THE JOURNAL OF
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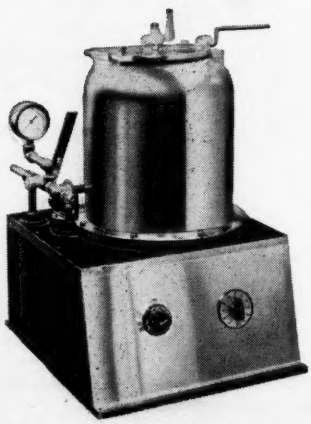

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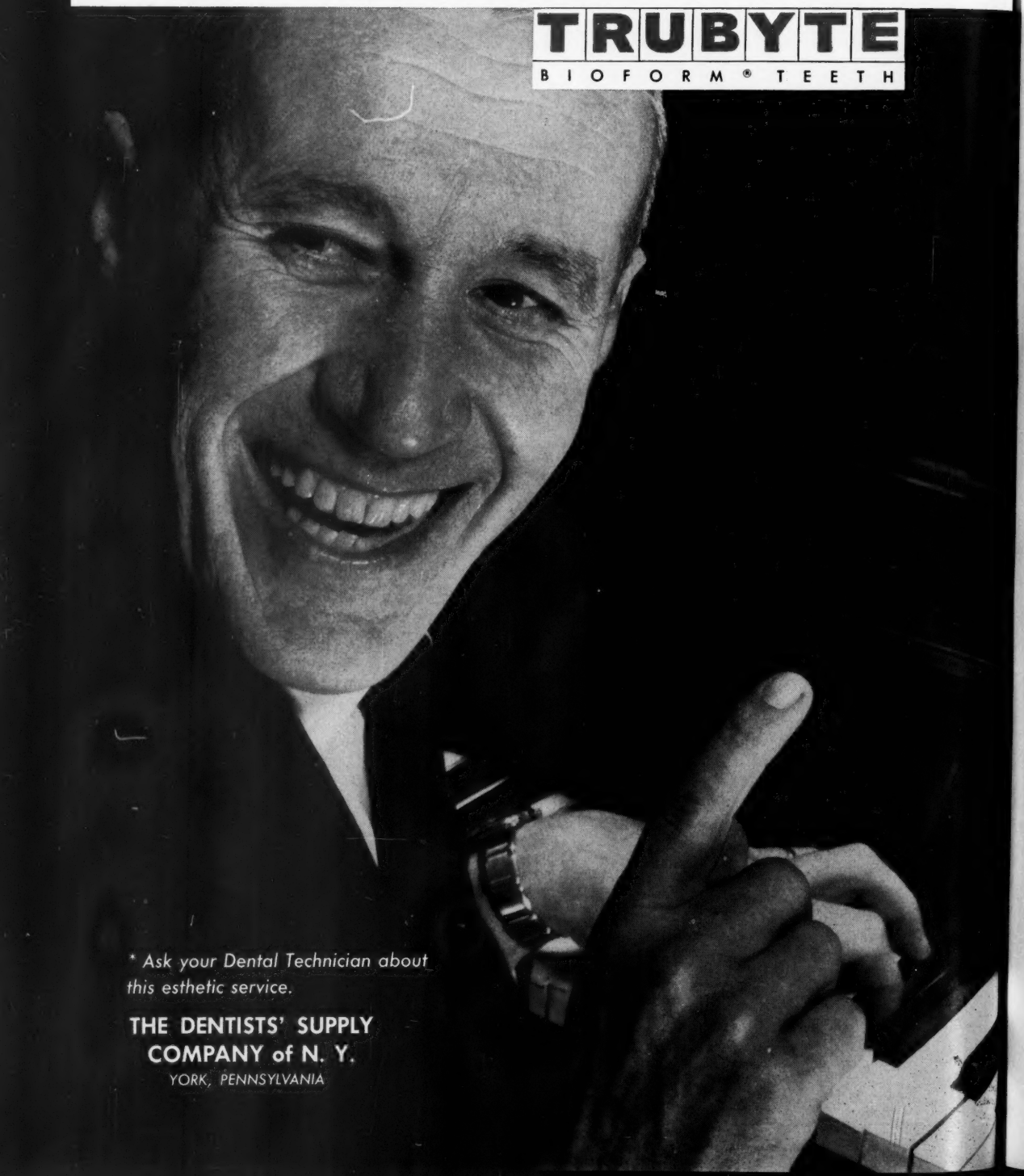

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THROUGH THE EYES OF THE EDITOR

G. A. Lammie associates the shrinkage of the residual alveolar ridge with atrophy of the mucosa covering it. He relates this process to aging and other factors. He suggests that shrinkage of the mucosa may cause the molding of the bone. He points out the soft tissue changes which occur in aging and hormonal deficiencies or disturbances. He does not overlook the effects of the presence of dentures and reports clinical observations on two types of ridge foundations. This problem is worthy of further study.

Clinton F. Sobolik discusses the bone changes that occur after the teeth are removed. He points out that some of them are inevitable, but some may be controlled. His suggested procedures should tend to minimize the changes. The problems of diagnosis, prognosis, and control of the amount of bone changes under dentures require much more research before they can be solved completely.

Martin Henry Berman discusses interocclusal records and reports his tests of the relative amount of force required for making them. He suggests that records made without closing pressure are more accurate than those made with closing pressure. This philosophy would satisfy those who desire to have the teeth meet simultaneously at their very first contact, but it would not be acceptable to those who desire to have the closing pressure distributed evenly under heavy closing pressures. He suggests the use of zinc oxide and eugenol for these records. The technique can achieve his objectives if it is carried out carefully.

Don N. Brotman reports his mathematical analysis of the effects of incorrect orientation of the casts to the axis of the articulator. He shows by means of formulas that errors in occlusion are least with an accurately located hinge axis and greatest with an arbitrary mounting of casts (mounted without a facebow).

Finn Tengs Christensen suggests a formula for determining the compensating curve in relation to the type of teeth being used. The mesial inclines of the lower cusps are considered the same as the occlusal surfaces of cuspless teeth that are inclined so they make continuing contacts throughout protrusive movement. Stating this another way, cuspless teeth set on a curve so that they contact throughout protrusive movement are comparable to the mesial inclines of cusp teeth set in balanced occlusion. The formula shows the interrelationship of cusp height and the compensating curve as factors of occlusion. Naturally, these factors must be related also to the inclination of the occlusal curvature, the incisal guidance, and the condylar guidance.

Elmer T. Duncan and Sidney T. Williams report their studies of vertical dimension. Cephalometric roentgenograms were used to compare the occluded and the rest vertical

dimensions of 10 patients before the extraction of the remaining teeth, with and without dentures. Considerable variation in the face length was found by this means. The results indicate that the arbitrary establishment of an average interocclusal distance at rest position is not a reliable procedure. Most other methods are subject to similar errors. Their conclusion that the pre-extraction records provide the most accurate means for determining the correct vertical dimension of occlusion seems to be supported by their data. Further research *may* reveal that even pre-extraction records may be unreliable for *some* patients. This could occur when a patient's natural teeth are too large or too small for the musculature or when occlusal abrasion has shortened the teeth faster than their ability to erupt.

George Franklin McGee discusses the effect of some of the "rules" for positioning teeth on dentures and for shaping the denture bases. He points out the errors which result from following these rules and emphasizes the importance of placing teeth in their natural positions. The guides that he suggests for placing teeth correctly in their natural positions are practical and simple to use. It is only when the artificial teeth are in the same basic positions as the natural teeth, and when the denture-base contour is the same as that of the mucous membrane before extraction, that the lips and cheeks can be properly supported for esthetic appearance and facial expression.

Stig G:son Östlund reports his tests, on 10 denture patients, of the importance of saliva to the retention of complete upper dentures. His method has advantages over methods which have been reported previously. The results indicate that the amount of retention is related to the amount and viscosity of the saliva.

E. A. Travaglini, P. Gibbons, and R. G. Craig report their tests of the various resilient liners for dentures. All of them seem to meet *some* of the requirements the authors have set up and all of them seem to fall short of the ideal in some respects. Since their deficiencies differ, it is apparent that the material that will come closest to meeting the specifications for a particular situation should be chosen. They point out the need for further technical and clinical evaluations of this type of denture-base material.

Hasan N. Kubali discusses the retention of dentures and describes his "functional vacuum method for retaining dentures." The dentures developed by this technique depend upon atmospheric pressure as the retentive force. The palatal part of upper dentures is omitted, and this would place all occlusal force on the ridges. When the maximum coverage within the limits of health and function of the tissues is not used, an unnecessary load is placed on the tissues that are covered. This and the interference with the normal circulation of blood (by the heavy border seal) would promote bone changes. Nature abhors a vacuum, so it is unlikely that a true vacuum could be maintained under a denture for an extended time. It is likely that the soft tissues would proliferate in a short time to fill the spaces. The palateless denture would allow more space for the tongue, but this does not seem to be a major advantage.

Joseph S. Landa continues his discussion of denture difficulties and their diagnosis and treatment. In this article, he discusses denture-sore mouth and inflammation in the oral cavity. He points out the need for distinguishing between inflammation of local and systemic origin. This is essential or some lesions will not be diagnosed properly and some dentures will be ruined by relief that is not indicated.

Julian B. Woelfel, Judson C. Hickey, Ralph W. Stacy, and Lloyd Rinear report their findings on muscular activity during specific jaw movements. The measurements of electromyograms of 10 subjects making seventeen different jaw movements were statistically analyzed. The results are correlated to show the activity of each muscle for each movement in descending order. Their data lend electromyographic support to muscle functions previously discussed solely on terms of anatomic findings. The information obtained about the external pterygoid muscle is directly applicable to current discussions on condylar movement.

George Ward Glann and Ralph Carson Appleby discuss the preparation of the patient and his mouth for removable partial den-

tures. They classify these patients according to their general health and the chances for successful treatment. Many different approaches are used, and the examination consists of more than a simple listing of the existing conditions. The suggested procedures should improve the chances for success if they are carefully executed.

William H. Pruden II discusses the role of study casts in diagnosis and treatment planning. He suggests that they must be made accurately and mounted by means of a facebow on an adjustable articulator in centric relation. If this is done, many errors in treatment planning can be avoided.

Lawrence A. Weinberg discusses oral function and the role of articulators in making restorations which will be in harmony with mandibular movements. He distinguishes between masticatory and nonmasticatory function and relates the mandibular movement in each type of function to articulator movements. He points out the limitations of various types of articulators and suggests a means for correcting the errors resulting from them. It is significant that a concept of jaw motion and occlusion is necessary if the errors are to be eliminated. If the errors are recognized, they can be corrected. No instrument is capable of doing this for us, even though some articulators are more nearly accurate than others. The disharmonies in occlusion, from whatever cause, must be eliminated in order to protect the soft tissues and bone of the masticatory apparatus from damage.

Herbert Berman and L. Paul Lustig describe their technique for constructing restorations which protect the teeth and at the same time permit safe temporary cementation. They use the telescopic crown as the basis for the technique. The inner crown (thimble) is cemented permanently, and the outer crown may be placed safely with temporary cement. Many advantages are apparent; the disadvantage might be in the necessary bulk of the restoration.

David C. Hoppenstand describes the construction and operation of an apparatus for silver plating polysulfide impressions before the dental stone is poured into them. The casts have durable surfaces that will not be marred by the necessary fitting of restorations on them and offer a good contrasting color.

Lawrence A. Weinberg discusses full-coverage restorations and their effects upon the health of the gingivae. He describes his objectives in contouring veneer crowns for esthetic appearance, and he suggests a technique for making these restorations. If the technique is properly and carefully carried out, it should produce restorations which have an excellent appearance and which will protect the gingival tissues.

Janet Travell discusses temporomandibular joint disturbances which result from muscle spasm in the skeletal muscles of the head and neck. She maps potential trigger zones in the skeletal musculature in relation to the location of the referred pain. Limitation of the amount of opening of the jaws is a factor in diagnosing spasm of the muscles of mastication. The treatment suggested involves anesthetizing the trigger zones. The development of muscle spasm from emotional stress, extensive dental operations, or occlusal disharmony may account for the complaints of patients about pain in the temporomandibular joints under these circumstances. Further study along this line is indicated.

H. J. Merkeley classifies temporomandibular joint disturbances according to their causes and suggests treatments to correspond to each class. An accurate differential diagnosis is necessary before treatment is instituted.

G. H. Gibb discusses the reasons why gold-foil restorations are effective and the reasons they are not being used as much as they have been in the past. He suggests five steps for increasing the skill and confidence of dentists in the use of this material. He does not believe that enough experience in the use of gold foil is currently being required of dental students.

Everett M. Finger favors the use of gold inlays in gingival-third cavities in posterior teeth. He describes both his direct and indirect techniques for making these restorations. The construction of a tray to carry the impression material is the key procedure. If the techniques are carried out carefully, excellent fillings should result.

Devereux C. Josephs discusses the impact of the rapidly increasing amount of knowledge available today upon the need for continuing education. He points out some of the changes that have come about as the result of this explosion of knowledge. While his discussion relates primarily to other areas of living, his concept applies equally well in dentistry. Changes have occurred in dentistry, and a dentist who practices as he did even 5 years ago is practicing obsolete dentistry in some areas. Dentists have an obligation to continue their education by all of the means at their disposal, such as reading current dental journals, attending dental society lectures, postgraduate courses, and study clubs, and reading new books. The material for continuing education in dentistry is available, and we must use it or our progress will not keep up with our potential.

—*Carl O. Boucher*

COMPLETE DENTURES

THE REDUCTION OF THE EDENTULOUS RIDGES

G. A. LAMMIE, PH.D., M.D.S., B.SC., H.D.D., L.D.S.
Coventry, England

A REDUCTION IN THE HEIGHT AND WIDTH of the edentulous ridges always follows loss of the teeth. The amount of reduction varies and is of great prognostic importance when dentures are to be constructed. The term "ridge resorption" is used for this change of form but is inacurrate, since the same term is applied to a removal of bony trabeculae, either in a physiologic or pathologic situation. Ridge reduction is always accompanied by resorption of the bone of the ridge. However, resorption is not invariably accompanied by change of ridge form.

Dentists have been inclined to think that ridge reductions are caused solely by the traumatic effect of pressure from an overlying denture. However, flat ridges posterior to natural anterior and premolar teeth are seen regularly where no denture has been worn.

One basic observation must be made about such an edentulous ridge. When the ridge is well preserved, it is always covered by a mucous membrane and submucosa of considerable thickness. If the ridge is flat, it is always covered by a mucous membrane and submucosa of reduced thickness.[1] This may be confirmed clinically by palpation and observation or by microscopic investigation.

Ridge reduction is associated with atrophy of the overlying mucous membrane. It is postulated that this atrophy, which results in a reduction in the number of epithelial cell layers and the thickness of the underlying connective tissues, also manifests itself in a reduction in the surface area of the oral mucosa. This is apparent when two edentulous conditions are compared, the one showing well-formed ridges and the other very flat ridges. As atrophy progresses, the form of the mouth in coronal section changes from an undulating and invaginating shape to a more spherical one, with concommitant reduction in surface area (Fig. 1).

The atrophy of the oral mucosa, and the gingivae in particular, is not something which occurs only when the teeth are lost. It is the same atrophy which Stones[2] describes as presenile or senile atrophy of the gingivae that causes exposure of the roots of the teeth and retraction of the interdental papillae, a circumstance which predisposes the oral area to periodontal disease. Although the reduction in

surface area of the mucosa has not been discussed in the dental literature, a renowned general surgeon, René Leriche,[3] states: ". . . if the [edentulous] gums of those patients are carefully examined it will be seen, in fact, that *their mucous membrane appears to be too restricted for the bulk of bone however atrophied—that it has to cover.* It is stretched over the bone as over a frame, and has lost its pliancy."

HYPOTHESIS OF THE MECHANISM OF RIDGE REDUCTION

Two actions are postulated for the mechanism of ridge reduction. The first is an external molding force on the bony ridge. The most important force of this kind is the pressure applied to the ridge by an atrophying mucosa tending to establish a reduced surface area.

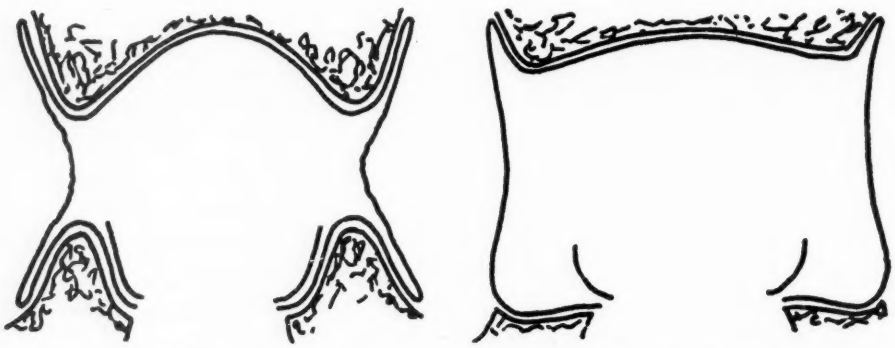

Fig. 1.—A reduction in area of the oral mucosa is associated with ridge reduction.[1]

This externally applied molding force meets more or less resistance from the bone itself, and this is the second action involved. These two variable actions are independent with common regulatory mechanisms which sometimes act on both. An acceptance of this dual interplay of externally applied force and resistance can account for all the different clinical pictures of ridge reduction.

Where the mucosa shows little tendency to contract and the bone form is well preserved, a well-formed edentulous ridge which is covered by a soft tissue layer of significant depth results. This is often seen in young adults who have lost their teeth because of caries.

Where the bone form is resistant but the mucosa is atrophying, the ridge reduction is not marked but the bone is covered by a tight, thin, soft tissue. Often the ridge is not smoothly curved but maintains an irregular outline. This condition sometimes has a racial distribution and is often seen in Indians.

By contrast, the bone form may not be well maintained, but the mucosal atrophy may not be marked. Here the result is the well-known fibrous ridge.

Where bone resistance is low and mucosal atrophy marked, gross ridge reduction is noted. This ridge form is seen especially at the menopause and in severe atrophy in the aged.

A final clinical situation is the denudation of the frame of an implant denture without ulceration. The static frame is exposed as the mucosa atrophies; this relieves an otherwise pathologic tension in the investing tissue.

ATROPHYING MUCOSA AS AN EXTERNAL MOLDING FORCE

Healing follows a definite sequence when skin is removed. A blood clot first occupies the wound and is replaced quickly by granulation tissue. A covering of epithelium is formed quickly over the granulations. However, this epithelial tissue is temporary in nature and differs histologically and functionally from the skin. The various strata of the skin are not recognized, and the number of cells constituting the thickness of the tissue is fewer. The condensation of ground substance known as basement membrane and the differentiation of reticular fibers are missing. This epithelium is a weak and transient structure and is replaced by true skin which covers the wound in one of two ways: (1) The skin may be drawn across the deficiency, this allowed partly because of its elastic quality. (2) There may be "intussusceptive" growth of new skin from the edges of the wound toward its central point. The degree to which each form of healing takes place depends on many factors, one of which is age. The potentiality for growth of all tissue, except neoplastic, decreases with age.

A similar series of events takes place when a wound caused by dental extraction is examined as it heals. First, granulation is covered by a temporary epithelial tissue which appears thinner and a deeper red than does the adjoining mucosa. The temporary tissue is depressed somewhat below the rolled edge of the normal mucosa at the edge of the wound. As healing proceeds, the normal gingival mucosa completely replaces the transient tissue, one rolled edge buccally or labially approaching the other palatally or lingually. If the potentiality for intussusceptive growth is marked, less reduction in ridge contour is noted. When, however, this possibilty is reduced, it can only be compensated by an inward movement of the existing mucosa. Since the union of gingivae attached to bone is strong, the bony plates must follow the movement of the migrating mucosa. This latter action must be proportionally more conspicuous in the elderly person where intussusceptive growth is less active; therefore, ridge reduction is often more marked.

This difference in intussusceptive growth potentiality accounts for the differences in ridge form established at the end of a 3- to 12-month healing period. Ridge reduction through mucosal action seen any time after this period must be caused by another mechanism.

Ridge reduction occurs at all stages of adult life, but for many years reduction may be so insignificant as to be clinically unimportant. There are two periods, however, when loss of the ridges associated with an atrophying mucosa takes place quickly. The first period is at the menopause and the second is when aging atrophy makes a more rapid onset.

All menopausal changes and symptoms are caused by changes in hormonal balance. In particular, there is a reduction in estrogen output which is known to have an atrophic effect on epithelial surfaces. The number of cell layers is reduced

as is the potentiality to keratinization. In addition, there is also a reduction in surface area which affects the genital epithelium, oral mucosa, and skin. The loss of vaginal plicae is the most marked of these reductions, and the skin surface loss the least marked. Controversy exists over the value of local application of estrogen to combat change in the skin, and local application has never been tried in the mouth. If a marked change in the skin is obvious, marked oral atrophy can be expected. It is usually possible to predict the ridge form by examining the skin of the face.

In atrophy which is due to age, the epithelial effect may be more or less marked, and it is probable that this reflects the hormonal picture. Geriatric texts describe the facial skin of the aged as being loose and wrinkled. Such skin form is often seen, but it is probably not so common as a tighter, smoother, and thinner skin. It is generally possible to predict the ridge form from the amount of skin atrophy.

This involution of facial and oral epithelium at the menopause and as atrophy in the aged, especially in men, suggests the possibility of secondary sex characteristics with the ketosteroid hormones playing a significant part. Substantiation is gained from the lip development at puberty and the growth spurt of the dental arches at this time to accommodate the eruption of the canine and premolar teeth. The lips and mouth also take on an erotic function.

RESISTANCE OF THE BONE OF THE RIDGE TO MOLDING

The development of the jaws is under genetic control to a large extent, although many claim that environmental influences play some less important part. As with all growth of bones, the somatotrophic hormone of the pituitary gland is an important mediator. Thus, during the final stages of growth and tooth eruption, an interplay of the development of three tissues contributes to final dental arch and oral form: (1) the development of the oral epithelium, attributed partly to the sex hormones, (2) the bone growth under the influence of the somatotrophic hormone, and (3) the tooth size, a third genetic variable. Dental arch form is therefore a complex issue, and it is little wonder that occlusal anomalies result and often do not respond to therapy based on mechanistic concepts. When the teeth are removed, the form is determined by the interplay of the external molding force already described and the resistance offered by the bone itself. Simple laws of physics apply to this system, and the final ridge form is the resultant of these competing vectors.

Although the resistance of the bone is referred to as a vectorial quantity, one is dealing with a living and changing tissue. Bone tissue has been developed to withstand imposed strain and will do this for a high order magnitude of force when the time of application is small. When the time of application is long, however, the magnitude of force that bone will withstand without biologic reaction is much reduced. The reaction to imposed strain is always osteolysis and remodeling. Bone remodeling is an osteogenic activity which results in a new bony form more able to withstand the applied strain without the development of that order of stress which induces further osteolysis. But stress may not be evenly distributed through-

out a bone, and osteolysis and remodeling will then be localized to zones of stress concentration. Such a mechanism is likely to pertain after the teeth have been extracted.

Immediately after the extraction of mandibular teeth, the outer and inner plates of bone are separated by septa of cancellous bone and the alveoli of the extracted teeth. The lamina dura is first removed and the alveoli are filled with coarse fibrillar bone, only much later by a mature cancellous structure. The potentiality to form cortical bone over the surface of the healing alveoli is not marked. Often none is formed and at best a thin, sometimes incomplete, covering is produced. In the maxillae, the external compact bony plates are thinner and the noncortical bone consists of more numerous, finer trabeculae. This structure often resists external forces better than does the bone of the lower jaw.

During ridge reduction after extraction there is concentration of stress in the bony plates. Little stress is accepted by the blood clot, the granulation tissue, or the fibrillar bone which successively occupy the space between the plates. Accordingly, within the plates themselves there are osteolysis and bone remodeling. *Macroscopically, this results in the cortical bony plates bending toward each other.* This is the appearance which is noted in surgical exposure and in dried specimens.

The resistance of the bony plates to this "bending" action depends on their degree of development. Not all regions of the mandible have the same tendency to yield under the constantly applied load of the atrophying mucosa. The thick bony plates in the molar and retromolar region, where the heavy external oblique and mylohyoid ridges converge, are virtually static in position. These regions are reinforced either to carry muscle attachments or to strengthen the bone at the change of direction from the body into the ramus where there is a concentration of load. This static position of the mylohyoid ridge often leads it to be projected above the general oral contour; the fact that the mylohyoid ridge is covered by a taut mucosa may lead to a serious denture problem. Other structures that resist molding are the genial tubercles. When marked ridge reduction occurs, the tubercles often lie above the general ridge contour and interfere with the development of a border seal on the denture.

The cancellous and fibrillar bone which lies between the bony plates also offers resistance, in varying degree, to deformation of the bony plates. The fact that ridge reduction is initially quick and gradually slows down may be partly accounted for by the relative weakness of the blood clot, the granulation, the fibrillar bone, and finally the mature cancellous bone which successively occupy the alveoli. Tissues of low strength occupy the spaces first, and stronger tissues are formed successively.

When ridge reduction occurs quickly at the menopause and with the onset of senility, there is accompanying osteoporosis. Albright[4] has attributed the osteoporosis that occurs at the menopause to the changed hormonal state, and especially to the estrogen reduction. The negative calcium balance seen in elderly persons has hormonal genesis and the possible additional complication of dietary insufficiency or defective absorption from the intestines.

McLean and Urist[5] state that ". . . atrophy of bone is unique and unlike atrophy of soft tissue structures. In soft tissues, such as skin, muscle, or liver, atrophy produces a reduction in the size as well as the number of cells and results in a shrinkage of the external dimensions of the whole organ. Atrophy of bone ordinarily occurs without a corresponding change in the volume of external dimensions of the bone, but the mass of bone tissue may be reduced as much as 75 per cent." This points to the action of some externally applied molding force to affect a change of bone shape. When the body of a vertebra collapses in Pott's disease, it is equally necessary to postulate a molding force; here it is the weight of the head, neck, and thorax.

THE ACTION OF A DENTURE BASE ON THE RIDGE

Although ridge reduction is caused mainly by contraction of mucosa, the bearing of a complete denture or a mucosa-borne partial denture base does play some part. The force developed under a denture is intermittent, rather than continuous, and is less likely to cause osteolysis. Often after a free-end lower removable denture has been worn for a short time, ridge reduction occurs and relining of the denture base is required. After the relining has been completed, it is often found that a relatively static condition is attained and further relining is not required for a considerable time. A similar situation is sometimes encountered with complete dentures.

A possible explanation of this clinical finding is that when a denture base is first applied over a ridge, an entirely new system of forces is imposed on the bone structure. These forces are different from those that existed when teeth were present or after extractions, but prior to making dentures. Wolff's law pertains to change of direction, as well as to the magnitude of load applied to bone. Accordingly, a change in direction of these loads results in a primary osteolytic effect which reduces the internal bone resistance and gives the external molding forces newly created opportunity to act. After osteolysis, however, there is a period of reconstruction of bony trabeculae and ridge reduction is halted.

Sometimes a localized high incidence of pressure causes circumscribed complete osteolysis and replacement of bone by fibrous tissue. Clinically, this is most often seen when a complete upper denture with porcelain teeth opposes natural anterior teeth in the lower jaw and a removable partial lower denture is not worn. It is not uncommon to find that the premaxillary region is fibrous and flabby. Here the mucosa has no further tendency to contract, but the bone has broken down as a result of heavy pressure.

SUMMARY

A hypothesis of the mechanism of ridge reduction has been discussed in the light of clinical observations. The action of the overlying mucosa in molding the edentulous ridge and the resistance offered by the ridge to this force were considered. The action of a denture on the ridge was described with particular reference to two clinical conditions.

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ALVEOLAR BONE RESORPTION

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THE AMOUNT OF ALVEOLAR (RESIDUAL RIDGE) RESORPTION after the extraction of teeth depends, in part, upon the extent of infection and the type of surgical operation performed. Although alveolar resorption is not under the control of the dentist, certain precautionary measures may be taken to minimize its extent.

Alveolar bone resorption may be of systemic origin (disease, faulty metabolism, or dietary deficiencies) or the result of trauma. The biologic factor may be disclosed through a complete and careful dental examination. The traumatic element may be reduced by a revision or modification of the mechanics of denture construction.

ORAL EXAMINATION

All too frequently the only examination made of the edentulous patient is a cursory inspection of the ridges. In dentistry, "examination has been defined[1] as the careful scrutiny of, and inquiry into the signs, symptoms, and all other factors associated with the condition to be examined. Diagnosis is the act or art of identifying the condition or conditions which are a departure from the normal."

A thorough examination of the edentulous patient includes history, psychologic investigation, visual and digital survey of the oral cavity, and complete-mouth roentgenograms. Although systemic disease may influence the rate and determine the type of alveolar bone resorption, the patient's history is often neglected. We are aware that the arthritic patient is subject to temporomandibular joint disturbances and that certain allergies may be manifested as stomatitis. Other systemic disturbances also adversely affect the alveolar process.

VITAL BONE CHANGES

Vital changes in the bone are caused by an interplay of destruction and formation of bone. The osteoblasts and the osteoclasts are the cells which participate in bone equilibrium. During growth and development, formation exceeds destruction. A balance is maintained in the healthy adult, and in old age, the osteoclastic element is in ascendance. We might conclude then that the most constant systemic factor of bone loss is the aging process.

Glickman[2] states: "The status of bone equilibrium is a variable, dependent on the physiologic and pathologic processes of the entire body for its regulation. When

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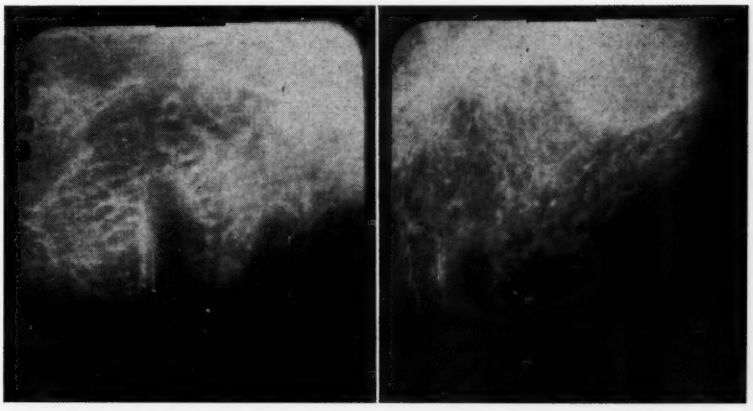

Fig. 1*A*.

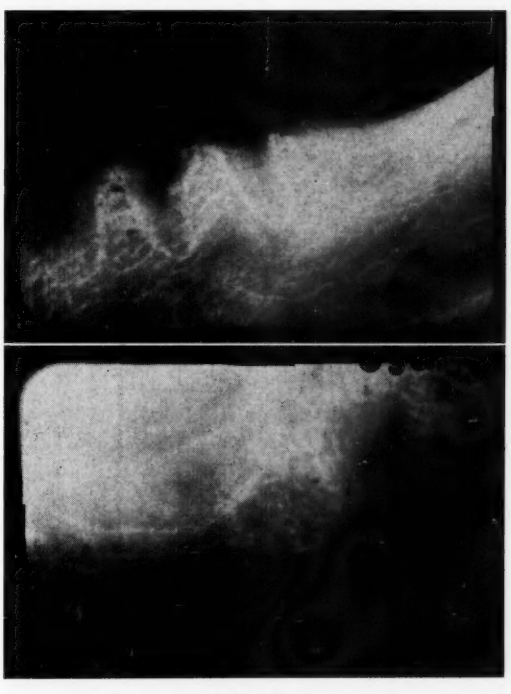

Fig. 1*B*.

Figs. 1*A* and 1*B*.—The bone is extremely porous in a diabetic patient 4 months after the extraction of teeth.

as a result of systemic disturbance, the microscopic equilibrium is shifted in favor of resorption, a similar condition prevails in the alveolar bone and loss of alveolar bone occurs regardless of the condition of the gingival tissues or the structural details of the prosthetic appliance." Kimball[3] reports: "There is sometimes a condition of osteoporosis which is associated with the menopause and postmenopause." Reifenstein[4] is of the opinion that some degree of osteoporosis is almost physiologic after menopause and that clinical evidence may be found in about 10

per cent of women over 50 years of age. Systemic diseases such as diabetes mellitus (Figs. 1*A* and 1*B*), tuberculosis, duodenal ulcer, syphilis, and the nephritides can affect bone metabolism and cause excessive atrophy of the alveolar bone.

The growth and repair of tissue are dependent upon a normal metabolic function, which in turn depends upon normal and correlated activities of the endocrine glands. The knowledge of this intricate system is rather limited. However, in hyperparathyroidism, calcium is withdrawn from the bones through osteoclastic resorption of the trabeculae of the bone. Bone in hyperparathyroidism presents a picture of osteoporosis. There is a marked resorption of the alveolar bone as well as the spongiosa of the jaws. Stahl, Wisan, and Miller[5] suggest that: "A disturbance in the protein metabolism might well interfere with osteogenic activity."

If the patient's history reveals a systemic disturbance which might adversely affect the prosthetic prognosis, a consultation with a physician is in order. Once the disturbance is under control, most of the systemic disturbances present no special problem in treatment planning.

DIETARY FACTORS

Foods are classified as proteins, carbohydrates, fats, inorganic elements, and vitamins.

Protein is necessary to build and maintain tissue and to supply energy. The necessary daily adult requirement of protein[6] is approximately 3 ounces, and the average American diet contains at least that amount. Aged persons need more than the minimum amount of protein for the maintenance of tissue health.

Carbohydrates (starches and sugars) provide the chief source of energy. They are related only indirectly to bone resorption through association with diabetes[6] and by substitution for more favorable foods.

Fats are organic substances that yield heat and energy and only secondarily build or repair tissue.

INORGANIC ELEMENTS

Calcium salts (calcium carbonate and calcium phosphate) form the rigid supporting structure of bones. Phosphorus, in the form of calcium and magnesium phosphates, gives hardness to bone. Abnormalities of the calcium-phosphorus elements of the blood stream may be associated with alveolar resorption or rarefaction. According to McCollum,[7] rickets may be associated with either a high calcium–low phosphorus or a high phosphorus–low calcium ratio in the blood content. There are low amounts of both calcium and phosphorus in osteoporosis.

The body requires 0.7 Gm.[6] of calcium per day, which can be obtained from 1 quart of milk. Other sources of calcium are dairy products, spinach, oranges, celery, chard, carrots, and lettuce. The phosphorus[6] need is from 1.5 to 3 Gm. daily, dependent upon the form. These requirements may be filled by dry beans, milk, cheese, leafy vegetables, celery, and carrots.

Since about 70 per cent of the magnesium in the body is in bone tissue, the structure of bone is dependent upon this mineral.[6] It is not a dietary problem, however, since it is contained in nearly all foods.

Iron, iodine, sulfur, copper, fluorine, and water have no direct bearing on bone growth or loss. They affect the bone only as they might affect the general health of the individual.

VITAMINS

In addition to proteins, carbohydrates, fats, and minerals, the diet must contain vitamins for development, growth, and function of the body.

Vitamin A.—A deficiency of vitamin A may result in poor development of calcification of the bone. However, it would seem to have no direct relation to the prosthodontist's problem.

Vitamin B Complex.—Deficiencies of vitamin B are related to bone resorption only so far as they may affect the general health of the individual.

Vitamin C.—Lack of vitamin C causes decalcification of the bone and has been held responsible for diffuse alveolar atrophy.

Vitamin D.—Deficiencies of vitamin D disturb the calcium-phosphorus balance and promote bone resorption.

Many drugs apparently act as vitamin antagonists. These drugs act largely on vitamins C and B complex, and their excessive use may cause a marked vitamin deficiency. Some of the common vitamin inhibitors are nicotine, alcohol, barbiturates, morphine, some of the sulfa drugs, and some of the antibiotics such as streptomycin and penicillin.

Edentulous patients should follow a prescribed dietary regimen. This diet should be low in carbohydrate and high in protein intake. The diet should include at least a quart of milk or substitute dairy products daily, vegetables, fruits, and a multiple vitamin supplement.

ROENTGENOGRAPHIC EXAMINATION

Unfortunately, the roentgenographic examination of edentulous ridges is not a routine procedure. Its purpose is to detect pathologic conditions, roots, impacted teeth, and foreign bodies which lie beneath the mucosa. This examination also permits alveolar bone to be studied and classified with regard to foundational potentials (Figs. 2 and 3). Roentgenograms aid in predicting the rapidity of bone destruction and the probable prognosis of the dentures.

Alveolar bone has two structural characteristics. A hard compact outer layer is superposed on a spongy, netlike, and somewhat resilient substructure. This architectural design is similar to a bridge with its girders and trusses resting on solid abutments and is admirably adapted to withstand functional stress.

A healthy and thoroughly healed alveolar process presents the following picture. Underlying the mucosa is a layer of wear-resistant compact bone of varying thickness. Beneath this compact layer are bars, plates, or tubules of bone of varying thickness and length. The spaces between the trabeculae communicate throughout the spongy bone. The bony trabeculae of the alveolar process are vertical to the stress forces, and this formation affords maximum resistance to masticatory efforts. The rapidity of bone destruction is in inverse proportion to the uniformity of density of the alveolar support.

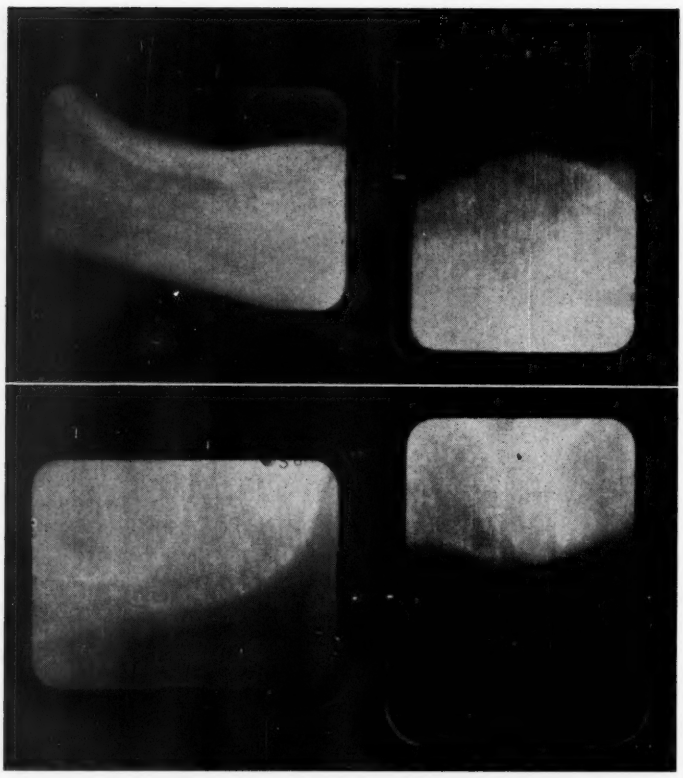

Fig. 2.—Dense alveolar bone provides good foundational possibilities.

STRESS CONTROL

Bone is generally thought of as a hard substance because of its rigidity, when in reality it is one of the most plastic tissues of the body. A blood vessel impinging on bone will form a groove. Bone is constantly undergoing changes in response to replacement and functional demands. As in every body structure, cell growth in bone is a continuous process. A rapid increase takes place in development and growth or in response to injury. As in other tissues, cell growth in bone is essentially a replacement of dead cells.

Wolff's law postulates that all changes in the function of bone are attended by definite alterations in its internal structure. Forces within the physiologic limits of bone are beneficial in their massaging effect. On the other hand, increased or sustained pressure, through its disturbance to the circulatory system, produces bone resorption. The amount and frequency of stress and its distribution and direction are important factors in treatment planning.

AMOUNT OF STRESS

Numerous investigators[8] have stated that under the most favorable ridge conditions, patients can tolerate only one-eighth of the masticatory pressure on

dentures as compared to their natural dentition. Brudevold,[9] in an experiment involving an edentulous patient with favorable ridges, noted that the greatest force exerted in a single "chew" was 8.5 Kg. or 18.7 pounds. Forces ranging from 30 to 170 pounds were required for the proper mastication of various meats and up to 200 pounds of force was necessary for dried bread or hard rolls. Apparently, some of the items of a modern diet present difficulties in mastication, as well as serve as potential causes of ridge resorption for edentulous patients.

Although the total amount of the necessary masticatory stress cannot be diminished, the unit work load may be lessened by increasing tissue coverage and decreasing the length and width of the occlusal table. Full advantage should be taken of hard compact bone, such as the palate and the mylohyoid and external oblique ridges (palatal relief is not indicated unless a maxillary torus is present). Posterior teeth that have been narrowed in both dimensions will more easily penetrate food, and the cusp form is superior to the flat occlusal type for the same reason.

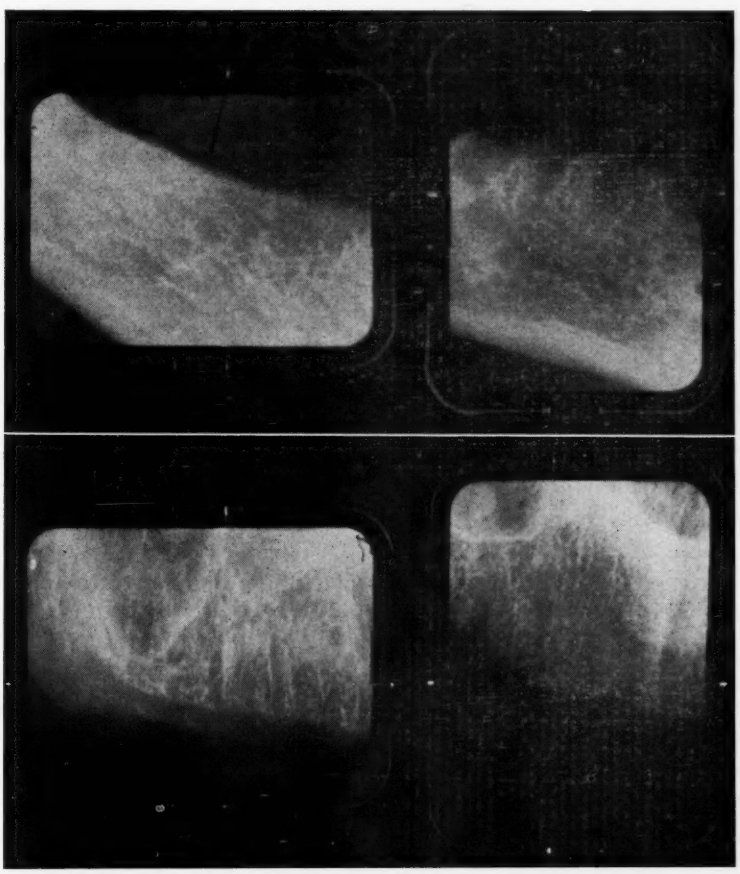

Fig. 3.—Porous alveolar bone will withstand little functional stress.

FREQUENCY OF STRESS

The frequency of the stress application modifies the reaction of alveolar bone to external forces. Constant pressure on bone causes resorption, while intermittent forces favor bone formation. According to my observations, it takes approximately 200 "chews" for a hard roll breakfast and up to or over 1,900 for a steak dinner.

Since recurrent forces over short intervals of time have essentially the same resorbing effect as constant pressure, a rest period between meals is beneficial. For this reason, the patient should be warned that gum chewing is a destructive habit to the bone.

Bruxism is an expression of nervous tension which manifests itself in gnashing, grinding, or clamping of the teeth while the patient is asleep or awake. Since most denture patients do grind their teeth in sleep, the dentures should not be worn during that period. Thus, the supporting structures are afforded the rest period essential to the maintenance of alveolar bone. While grinding of the teeth while awake may be a habit of tension, it may also be caused by a lack of interocclusal distance.

DIRECTION OF FORCE

Histologically, the trabeculation of the denture-bearing bone is arranged so that it will tolerate considerable force in the direction of the long axis of the teeth or at right angles to the base. It follows that horizontal forces should be avoided.

The principal concern should be in the pattern and position of the posterior teeth. There are two mandibular movements associated with mastication: a closing or cutting movement and a lateral or grinding movement. A sharp cusp will penetrate a bolus of food with less force than a flat occlusal form. However, a law of physics explains that forces applied to an incline plane produce a resultant force or vector, perpendicular, or at right angles, to the plane. Applying this principle to occlusal form, the resultant force of the steep inclines of high cusps would produce a lateral force which might cause alveolar resorption.

Certainly a compromise is indicated. A low cuspal inclination in a narrow buccolingual width provides a comparatively sharp cusp with more favorable bone direction. Horizontal forces are further minimized by placing the teeth as far lingually as possible without causing tongue interference or restriction.

STRESS DISTRIBUTION

Stress distribution favorable to healthy alveolar bone maintenance is dependent principally upon bilateral balanced occlusion. Balanced occlusion is that arrangement of the teeth which will permit the necessary mandibular movements without tending to dislodge the denture or traumatize the supporting structures.

Any balanced occlusion predicated on an incorrect centric relation must fail. If the balanced occlusion on the articulator is to prevail in the mouth, the casts must be mounted in the correct relation to the hinge axis of the patient. This

balanced occlusion must be maintained and refined by judicious selective grinding and milling to eliminate processing changes and cusp interferences.

This form of stress control, although probably the most important, is the one most frequently neglected.

SUMMARY

Alveolar bone resorption is one of the most important phenomena in denture construction. Some of the factors to be considered are:

1. Alveolar bone resorption after extractions is a normal process.
2. The patient's history may reveal systemic diseases which might cause resorption through circulatory disturbances or faulty metabolism.
3. Dietary deficiencies may induce bone loss.
4. Roentgenographic examination will reveal the possible capabilities of bone to resist external stresses.
5. Stress control through modification of construction procedures will minimize bone loss.

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ACCURATE INTEROCCLUSAL RECORDS

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RESTORATIVE PROCEDURES require the transfer of tooth and jaw relationships to some form of an articulator. Wax has achieved wide acceptance for this precise transfer, despite the fact that its inherent nature constitutes an opportunity for error.[1] While wax is a versatile material, it is far from the perfect medium for the registration of the critical interocclusal record.

IMPORTANCE OF CORRECT MAXILLOMANDIBULAR RECORDS

The final evaluation of any prosthesis depends upon whether the resultant maxillomandibular relationship is in harmony with the anatomy of the patient. This relationship is not the simple matter of mandibular opening and closing. It is a complex relationship which exists in three dimensions. Variations may occur in the vertical, anteroposterior, or mediolateral position. In addition, the vertical variation may be dissimilar on the two sides.[2]

The introduction of waxes with varying degrees of fluidity between the teeth is often a responsible factor in inducing displacement of the normal temporomandibular relationship. The ability of the mandible to reposition itself to accommodate a bolus of sandwiched wax may not be evident to the dentist; nevertheless, it can, and does, occur.

Jackson[3] has described the centric position as the maxillomandibular relationship that permits the teeth to occlude in the normal functional situation with the mandibular condyles in a balanced position in the mandibular fossae.

The positions of the condyles in the fossae are subject to many influences. An accurate jaw position requires a motor act which is the result of proprioceptor impulses originating anywhere in the masticatory mechanism, or even from outside of the mechanism. Where periodontal proprioception is lost (as when teeth are lost), motor activity may be influenced even more by touch, pressure, and other painful stimuli arising from closures on the denture base.[4]

DENTAL WAXES

Dental wax may be hard or soft, thick or thin, or heated or chilled throughout its bulk without uniformity. Once the record is made, it is subject to being scraped, blunted, distorted, and compressed. At best, the inherent variable nature of wax precludes its suitability as a recording and transferring material for so critical a relationship.

Ideally, the material used to obtain precise interocclusal records should offer no resistance to closure, have true fluidity, and permit the masticatory mechanism to operate *free from strain.* Silverman[5] states that an accurate centric relation record can be obtained only with *minimal* closing force. Any attempt to make a record with anything more than minimal closing force generally leads to an incorrect centric relation.

The report of the Principles, Concepts, and Practices Committee of the Academy of Denture Prosthetics[6] states that, "A centric jaw relation record that is used for relating the mandibular cast in the articulator should represent an *unstrained* [italics mine] maxillary and mandibular ridge relation. . . . " Lytle[7] has demonstrated that tissue distortion takes place under denture bases subject to stress and has emphasized the importance of softness of the recording materials.

RECORDING MEDIA

The material utilized to obtain this important record has much to do with its resultant accuracy. The choice of materials narrows down to plaster, wax, modeling compound, and zinc oxide and eugenol impression paste. Plaster flows readily, but, because it must be mixed thin, it breaks easily, it lacks adherence, and vital parts of it may be lost. Modeling compound and wax share many similar features. However, wax has received the widest acceptance for obtaining the interocclusal record.

TESTING RESISTANCE OF WAXES

A device was designed to test the relative resistance to penetration of various dental waxes used for recording tooth and jaw relationships (Fig. 1). A platform was mounted on top of a rod that was calibrated and marked to a depth of 12.5 mm. (½ inch) at the tip. Penetration by the rod of a ½-inch thickness of warmed wax was considered full penetration.

The weight of the rod was established as zero. By adding weights to the platform, a load was built up sufficient to effect full penetration of the wax. The load required for full penetration was considered to be the resistance of the wax to penetration. Since a variety of waxes were tested, each was warmed to the stage

TABLE I. WEIGHT REQUIRED FOR COMPLETE PENETRATION

WAX	LOAD (GM.)
A	272
B	102
C	204
D	221
E	136
F	357
G	221
H	272
Zinc oxide and eugenol paste	0

that was considered proper for insertion into the mouth. Although this procedure introduces an unavoidable variable, it is the method used routinely by dentists.

RESULTS

The softest wax required a weight load of 102 Gm. for full penetration, while the hardest wax required 357 Gm. The load required for penetration of all waxes tested is seen in Table I. The zinc oxide and eugenol impression paste offered zero resistance to penetration (Figs. 2 to 4).

Regardless of the wax used, some force must be exerted by the patient to achieve the interocclusal record. Another variable is the masticatory muscular development and closing power of different individuals. When patient effort, variation in masticatory muscular capability, and temporomandibular joint displacements are

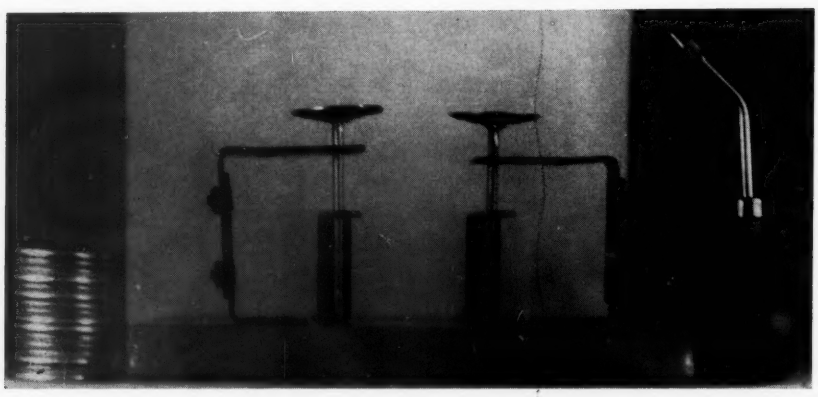

Fig. 1.—A device for measuring the resistance of dental wax to penetration. The weights are 17 Gm. each. The steel penetrating rods with the platform mounted on top are calibrated and marked at 12.5 mm.

combined, it is little wonder that wax interocclusal records are often clouded beyond recognition. These variable factors may account for the many conflicting records obtained from a single patient.

MATERIAL OF CHOICE

The material of choice for the interocclusal record is the zinc oxide and eugenol type of impression paste. This material mixes to a true fluid consistency, offers no resistance to closure, and adheres to its carrier. It sets to a hard, noncompressible consistency and is sharp and easily read (Fig. 5). Articulation of the casts may be accomplished accurately without fear of distortion or compressing the record unequally in the vertical dimension.

COMPLETE DENTURE RECORDS

Many dentists employ a procedure of repetitive pooling of wax and closures to establish the vertical dimension of occlusion and record centric relation.

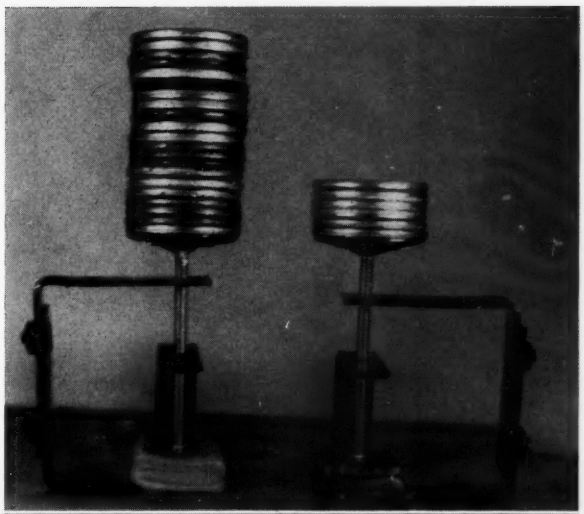

Fig. 2.

Fig. 3.

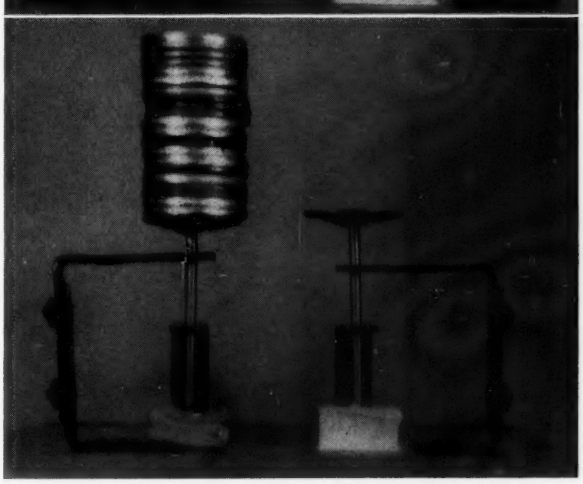

Fig. 4.

Fig. 2.—The wax on the right requires less load for penetration than the wax on the left.

Fig. 3.—Left, with zero added weight, the rod has made a negligible penetration into the wax. Right, with zero added weight, the rod has penetrated through the zinc oxide and eugenol paste.

Fig. 4.—A comparison is made between the weight required to penetrate the hardest wax (left) with the weight required to penetrate the zinc oxide and eugenol paste (right).

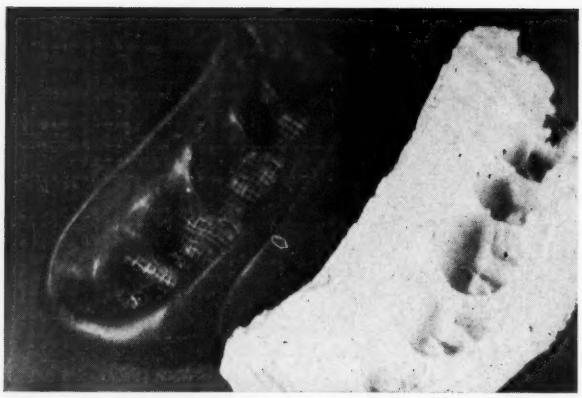

Fig. 5.—The zinc oxide and eugenol impression paste record gives much more detail than the wax record.

Generally, either a needle-point tracing or a wax interocclusal record is used for recording centric relation. Many dentists discard the needle-point tracing when it fails to agree with a subsequent wax interocclusal record. Apparently, wax seems to prevail as the recording medium in the end.

RECORDING JAW RELATIONS FOR COMPLETE DENTURES

The upper occlusion rim is made of hard wax on a trial base material. The rim is adjusted in the mouth according to the usual landmarks and chilled, and two V-shaped notches are cut into the occlusal surfaces in its posterior regions.

The lower wax occlusion rim is cut down by hand with a warm knife until the vertical dimension at occlusion has been "overclosed" about 2 mm. (Fig. 6).

Aluwax* is heated in the flame and dripped onto the lower occlusion rim in small mounds about 4 mm. high and 4 mm. in circumference. Three such mounds are formed, one in the anterior region and one on each of the posterior sides (Fig. 7). The mounds are *not* positioned directly below the V-shaped notches in the upper rim, since the record is not to be locked at this stage.

The Aluwax holds heat well and remains soft while the patient closes lightly into the mounds to a depth of about 2 mm. (Fig. 8). Because the area of contact between the upper and lower occlusion rims is reduced to three small mounds of soft wax, *minimum* closing effort is required. Thus, the strain which accompanies closing into a large surface area of wax is avoided.

The lower occlusion rim is removed from the mouth after the light closure into the Aluwax. Zinc oxide and eugenol impression paste is applied to the surface of the rim, and the rim is returned to the mouth. Since the vertical dimension has already been established, the patient closes lightly in centric relation, making only minimum contact of the rims. The feeling of maintaining the rims lightly in contact must be conveyed to the patient or the mounds of wax may be further

*Hickok Specialties, Grand Rapids, Mich.

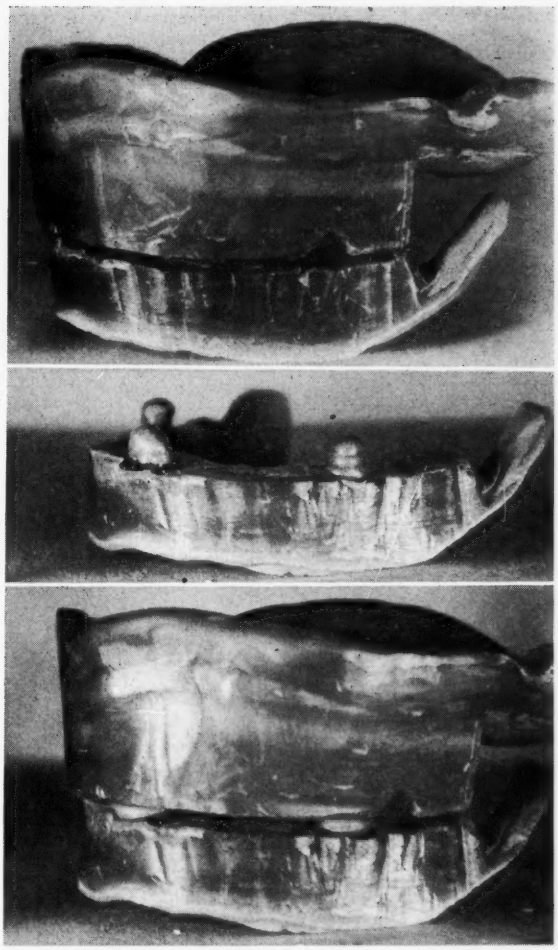

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 6.—The lower wax occlusion rim is cut down with a warm knife after repeated trials in the mouth. The vertical dimension is now overclosed about 2 mm.
Fig. 7.—Three small elevations of Aluwax are formed on the lower wax rim.
Fig. 8.—The patient closes into the Aluwax to a depth of 2 mm.

compressed (Figs. 9 to 11). If a needle-point tracing is used, the impression paste may be used to lock the record.

It is important to use an impression paste which mixes to a readily flowable consistency.* The paste should set hard in less than 2 minutes and record sharp detail. A rapid set of the material is essential to avoid the muscular fatigue which accompanies the maintenance of a fixed, closed position for a long period of time. The less muscular effort and strain associated with closure, the less erratic the record.

All subsequent interocclusal records made during the try-in, as well as the record for remounting the completed dentures, are made with this same material and method.

*Plastopaste, H. J. Bosworth Co., Chicago, Ill.

Fig. 9.

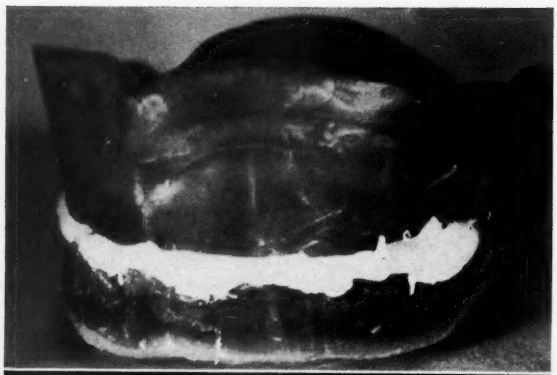

Fig. 10.

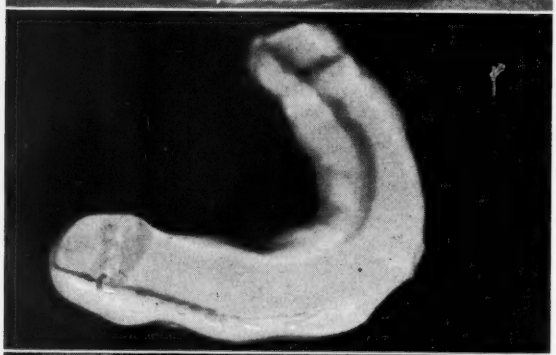

Fig. 11.

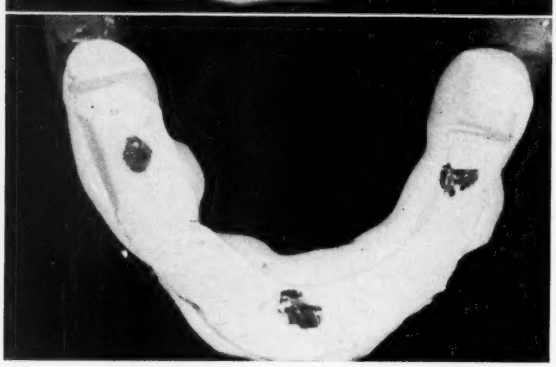

Fig. 9.—The final closure is made into zinc oxide and eugenol paste.

Fig. 10.—The occlusal surface of the lower rim after closure into the paste.

Fig. 11.—An incorrect record. The wax mounds are further compressed and visible through the paste by an unsatisfactory closure.

RECORDING JAW RELATIONS FOR FIXED PARTIAL DENTURES

The use of the gauze or foil wax wafer to make maxillomandibular records in fixed partial denture prosthodontics has been replaced by a unique wire frame device* designed for the use of zinc oxide and eugenol impression paste. The device consists of a wire frame shaped to fit the dental arch. The rear section of the

*Jones Bite Frame, R. J. Jones, Cleveland, Ohio.

frame passes distal to the last molar permitting unhindered closure of the teeth. A thin piece of gauze that is stretched across the wire frame receives and carries the impression paste.

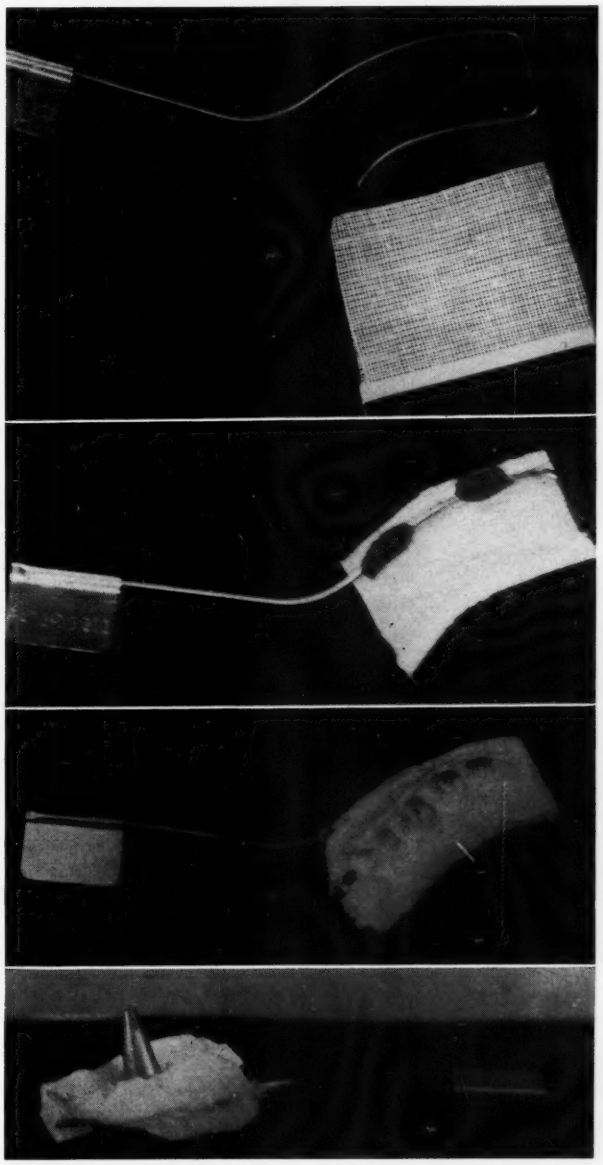

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 12.—The Jones interocclusal record frame and the interocclusal gauze.

Fig. 13.—The gauze is attached to the frame, and the free end is tacked down with red boxing wax.

Fig. 14.—A zinc oxide and eugenol paste interocclusal record is made using the frame.

Fig. 15.—A die is positioned in a zinc oxide and eugenol paste record.

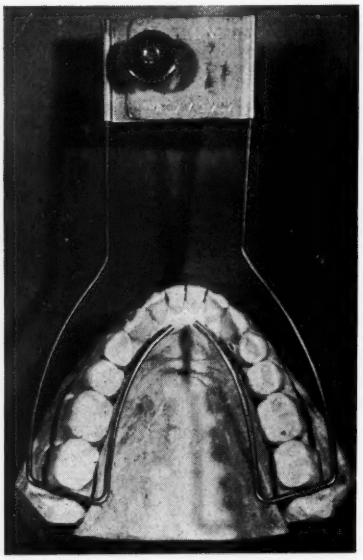

Fig. 16.—The frame may be used for a bilateral record.

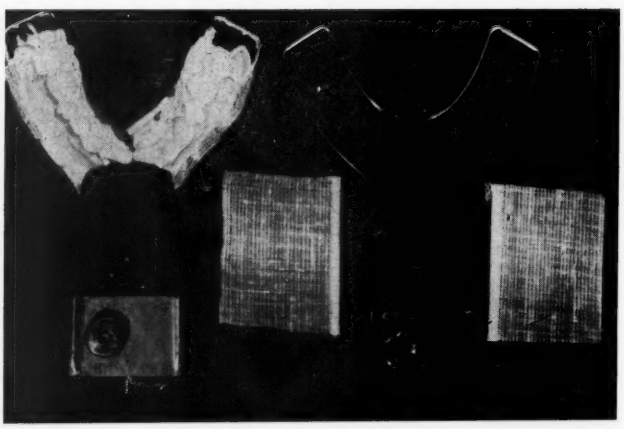

Fig. 17.—A zinc oxide and eugenol paste record is made of the complete dental arch.

The zinc oxide and eugenol impression paste is applied to both sides of the gauze, the frame is placed in the mouth, and the patient is instructed to close the teeth. The closure is made without effort or strain (Figs. 12 to 14).

The resultant interocclusal record is sharp when it is compared to a wax record (see Fig. 5). In fact, the record is so sharp that it may be used for the positioning of dies (except for the soldering assembly) (Fig. 15). The paste used for these records should be heavy bodied so it will not run off the gauze.*

*Opotow Paste for lower impressions, Opotow Dental Mfg. Co., Brooklyn, N. Y.

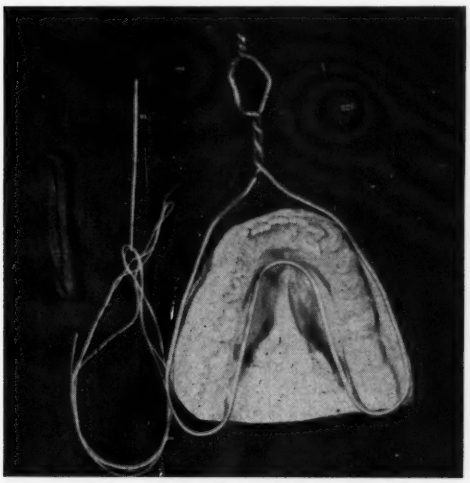

Fig. 18.—A fitted frame is made of 12-gauge galvanized wire. The wire is bent to fit around teeth on the study cast and clears the teeth by ¼ inch, buccally and lingually. The gauze is attached to the frame with a needle and thread and red boxing wax.

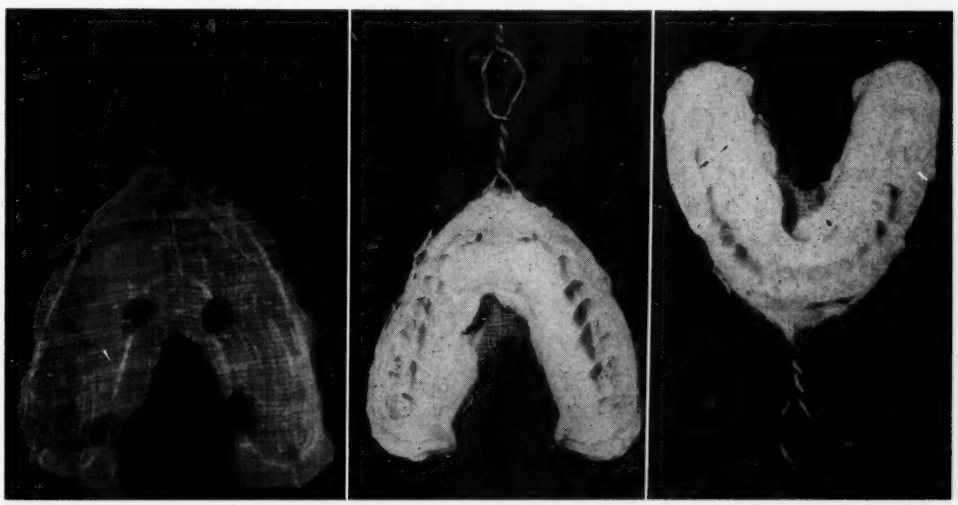

Fig. 19. Fig. 20. Fig. 21.

Fig. 19.—The gauze is sewed to the wire frame. Only the gauze on the labial and buccal side is stitched to the frame. The gauze on the lingual side is tacked to the frame with red boxing wax so the gauze will stretch during closure. The stitches on the outer frame may be anchored with hot sticky wax to prevent slippage on the wire.

Fig. 20.—A complete arch interocclusal record. Edentulous spaces not needed in the record may be blocked out in the mouth with Johns Manville Dux-seal.

Fig. 21.—The mandibular side of a complete arch interocclusal record.

The wire frame device may be used also to make a bilateral record (Figs. 16 and 17). However, a 12- or 14-gauge galvanized wire bent to fit the individual patient avoids many interferences and problems (Figs. 18 to 21).

SUMMARY

Whether dental waxes make accurate interocclusal records is questioned. Tests with various waxes indicate that all offer some resistance to closure.

Zinc oxide and eugenol impression paste offers no resistance to closure and possesses many qualities favorable for obtaining maxillomandibular records. A technique is described for the use of this paste in complete denture and fixed partial denture prosthodontics.

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HINGE AXES
Part II. Geometric Significance of the Transverse Axis*

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THE MECHANICS AND ANATOMY OF THE TRANSVERSE HINGE AXIS were discussed in Part I of this series. This article will consider the axis purely from the aspect of applied mathematics.

THEORETIC PROBLEM

Imagine a patient in whom a centric relation prematurity (deflective occlusal contact) is suspected as the source of an existing pathologic condition. As part of the diagnosis, the study casts of the patient's mouth are articulated and any necessary occlusal adjustments on these stone casts are made. The adjustments on the casts are made to determine if the occlusal adjustment is a practical procedure before the patient's teeth have been ground.

Hinge axis interocclusal records should be obtained at a greater vertical dimension of occlusion than the patient usually exhibits in order to prevent the teeth from contacting. If the teeth contact while the hinge records are being made, the inclined planes of the contacting cusps may malposition the lower jaw (Fig. 1). If the lower jaw is malpositioned, the records obtained will not be correct and will not be suitable for either mounting the lower cast or checking its position.

After mounting the casts in their proper hinge axis relationship, the established vertical dimension must be reduced on the articulator (the casts must be brought into contact) to find the first deflective occlusal contact. Then, as the occlusion is adjusted on the casts, the vertical dimension will be reduced even more. It is possible to compute how much occlusal error is developed if the hinge axis has been improperly located and the articulator has been closed. The computations are based upon a comparison of two articulators, with casts mounted correctly on one to duplicate the relation to the transverse hinge axis of the patient and on the other incorrectly mounted because the patient's transverse axis movement was not located accurately.

CALCULATING OCCLUSAL ERROR

In Fig. 2, line A is a straight line connecting hinge dot P (on the skin) to the mesioincisal angle of the lower central tooth of the same side *(1)*. Lines B and C are constructed to make a right triangle with A as the hypotenuse. Mathematically,

*Part I. The Transverse Hinge Axis, J. PROS. DEN. 10:436-440, 1960.

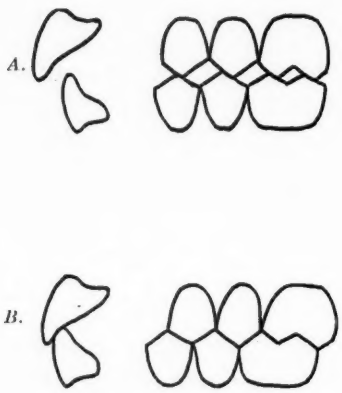

Fig. 1.—*A*, The initial contact relationship of the teeth when the mandible is closed in the hinge axis position may seem to be a retruded one. *B*, When the cusps are allowed to slide upon one another, a protruded relationship of the mandible to the maxillae results if the hinge axis position is an unstable one (cusp tips contacting inclined planes). This protruded position of the mandible has been called the "acquired" or "habitual" eccentric position. The protruded position is avoided when one is making hinge axis interocclusal records.

any right triangle may be used for computations, but a right triangle with sides of 5, 12, and 13 units will be used here because of the convenience of dealing with whole numbers.

Let A_0 (Fig. 3) equal 120 mm.; then, B_0 equals 46.15385 $\pm$ 0.00001 mm. and C_0 equals 110.76923 $\pm$ 0.00001 mm. A_0 equals 120 mm. *in this example* no matter at what vertical dimension the hinge axis interocclusal records are made, because A_0 is the radius of the circle of which P is the center. If the interocclusal records are made at the vertical dimension of $B + x$ mm., x is the number of millimeters the mandible must move vertically to reach occlusal contact.

EFFECT OF DIRECTION OF ERRORS

Before determining the exact magnitude of the errors, we will determine how the direction of the errors influences the occlusal relationship. For this purpose, assume the position of the hinge dots to have been improperly located by 5 mm. in

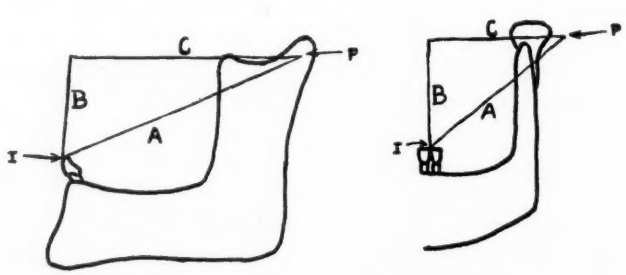

Fig. 2.—*A* is the line joining hinge dot *P* to the mesioincisal angle of the lower central tooth of the same side *(I)*. *B* and *C* are constructed so as to form a right triangle with sides of 5, 12, and 13 units.

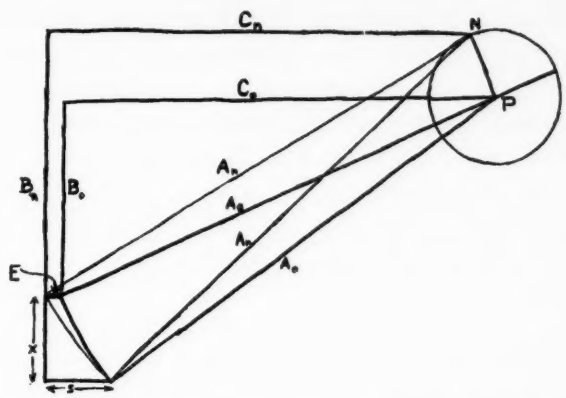

Fig. 3.—Improper relation of the maxillary cast to the hinge axis affects the closing of the articulator even though an accurate interocclusal record was used to orient the lower cast. *P* is the true position of the hinge axis. *N* is the point at which the axis was improperly placed. A_o is the correct hinge axis closure path. A_n is the closure path for the case in which orientation is incorrect. The amount of occlusal separation present when the hinge axis interocclusal record was made is represented by *x*, and *s* is the distance the mandibular cast moved forward as the articulator was closed from the level of the interocclusal record *(B + x)* to the occlusal contact vertical dimension *(B)*. *E* is the error $(C_n - C_o)$ at the level of occlusal contact and is potentially a problem in relating casts.

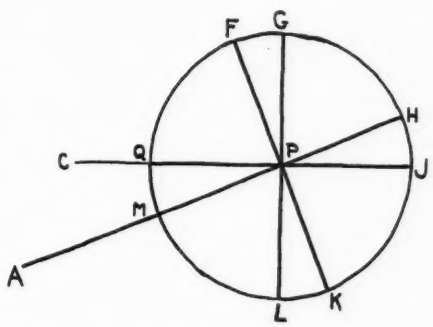

Fig. 4.—The circle has a radius of 5 mm. The various points marked on the circle are either on or perpendicular to line *A* or *C*.

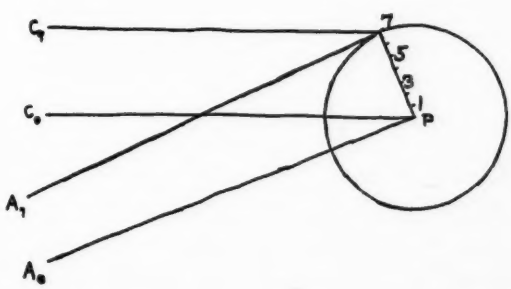

Fig. 5.—*P* is the proper position of the hinge dot. If *P* were improperly located at *N (n* mm. from *P)*, A_n would represent the line joining the incorrect hinge dot to the mesioincisal angle of the lower central incisor of the same side, *I*. C_n would be the line parallel to C_o, which joins A_n to B_n (which is parallel to *B*) so as to construct a right triangle.

TABLE I. VALUES OF B AND C AT THE DIFFERENT LOCATIONS SHOWN IN FIG. 4

LOCATION	VALUE OF B	VALUE OF C
F	$B_f = B_0 + 60/13$	$C_f = C_0 - 25/13$
G	$B_g = B_0 + 5$	$C_g = C_0$
H	$B_h = B_0 + 25/13$	$C_h = C_0 + 60/13$
J	$B_j = B_0$	$C_j = C_0 + 5$
K	$B_k = B_0 - 60/13$	$C_k = C_0 + 25/13$
L	$B_l = B_0 - 5$	$C_l = C_0$
M	$B_m = B_0 - 25/13$	$C_m = C_0 - 60/13$
Q	$B_q = B_0$	$C_q = C_0 - 5$

various directions. The error introduced when the lower cast is mounted with an interocclusal record of 5 mm. thickness and then the articulator is closed to occlusal contact will be computed.

Computations will be made in the following manner. First, the length of C_0 (Fig. 3) at the mounting record vertical dimension will be determined, then the

TABLE II. ERRORS WHEN MAXILLARY CAST IS INCORRECTLY LOCATED (FIG. 4)

LOCATION	WHEN $x = 0$	WHEN $x = 5$		
P	$C_p = 110.769$	$C_p = 108.551$	$S_p = 2.218$	$E_p = \pm 0.001$
F	$C_f = 108.846$	$C_f = 106.371$	$S_f = 2.475$	$E_f = +0.257$
G	$C_g = 110.769$	$C_g = 108.320$	$S_g = 2.449$	$E_g = +0.231$
H	$C_h = 115.385$	$C_h = 113.172$	$S_h = 2.213$	$E_h = -0.005$
J	$C_j = 115.769$	$C_j = 113.648$	$S_j = 2.121$	$E_j = -0.097$
K	$C_k = 112.692$	$C_k = 110.721$	$S_k = 1.971$	$E_k = -0.247$
L	$C_l = 110.769$	$C_l = 108.781$	$S_l = 1.988$	$E_l = -0.230$
M	$C_m = 106.154$	$C_m = 103.929$	$S_m = 2.225$	$E_m = +0.007$
Q	$C_q = 105.769$	$C_q = 103.444$	$S_q = 2.325$	$E_q = +0.107$

length of C_n at the vertical dimension at occlusal contact. $C_n - C_0$ gives the distance the lower cast moved forward *(s)* when the vertical dimension was reduced. The difference between the computed forward movement of the accurately oriented cast and that of the inaccurately oriented cast will be considered the error*(E)*. The

TABLE III. VALUES OF C WITH INTEROCCLUSAL RECORDS OF DIFFERENT THICKNESSES

x	C	x	C
0	110.769 $\pm$ 0.001 mm.	6	108.074 $\pm$ 0.001 mm.
1	110.347 $\pm$ 0.001 mm.	7	107.586 $\pm$ 0.001 mm.
2	109.915 $\pm$ 0.001 mm.	8	107.086 $\pm$ 0.001 mm.
3	109.471 $\pm$ 0.001 mm.	9	106.574 $\pm$ 0.001 mm.
4	109.017 $\pm$ 0.001 mm.	10	106.051 $\pm$ 0.001 mm.
5	108.551 $\mp$ 0.001 mm.		

possible incorrect locations of the hinge axis are seen in Fig. 4, and the calculations of the amount of error in Tables I and II.

Thus, the greatest errors occur when the hinge axis is incorrectly located in a direction which is perpendicular to line A. The smallest errors occur when the hinge axis is incorrectly located but is on line A.

If the casts are properly mounted and correctly related, the following measurements exist: $A_0 = 120 \pm 0.00001$ mm., $B_0 = 46.15385 \pm 0.00001$ mm., and $C_0 = 110.76923 \pm 0.00001$ mm. (Fig. 3). Therefore, $120^2 = (B + x)^2 + C_x^2$.

TABLE IV. ERRORS WHEN MAXILLARY CAST IS INCORRECTLY POSITIONED BY 7 MM. WITH INTEROCCLUSAL RECORDS OF DIFFERENT THICKNESSES

x	C_7	D_7	E_7
0	108.077 ± 0.001	−2.692 ± 0.001	±0.001
1	107.584 ± 0.001	−2.763 ± 0.001	−0.071
2	107.081 ± 0.001	−2.834 ± 0.001	−0.142
3	106.564 ± 0.001	−2.907 ± 0.001	−0.215
4	106.036 ± 0.001	−2.981 ± 0.001	−0.289
5	105.497 ± 0.001	−3.054 ± 0.001	−0.362
6	104.944 ± 0.001	−3.130 ± 0.001	−0.438
7	104.379 ± 0.001	−3.207 ± 0.001	−0.515
8	103.802 ± 0.001	−3.284 ± 0.001	−0.592

TABLE V. ERRORS WHEN MAXILLARY CAST IS INCORRECTLY POSITIONED BY 5, 3, AND 1 MM. WITH INTEROCCLUSAL RECORDS OF DIFFERENT THICKNESSES

x	E_5	E_3	E_1
0	±0.001	±0.001	±0.001
1	−0.050	−0.030	−0.009
2	−0.101	−0.060	−0.020
3	−0.152	−0.090	−0.030
4	−0.204	−0.121	−0.040
5	−0.257	−0.153	−0.050
6	−0.311	−0.185	−0.061
7	−0.365	−0.217	−0.072
8	−0.420	−0.250	−0.082

Now, suppose the casts are articulated so that the maxillary cast is 7 mm. from its proper position relative to the hinge axis. How will this affect the position of the mandibular cast in relation to the maxillary cast when the articulator is closed? Table III shows the length of C when the casts are properly oriented and the hinge axis has been properly located. Assume that the interocclusal record used to orient the lower cast to the upper one is an accurate record which was made while the mandible was in the hinge axis position. Let n represent the number of

millimeters of error between the maxillary cast and the hinge axis (Fig. 5). The computations for the greatest possible error under the stated conditions follow:

$$B_n = B_0 + 12n/13 \qquad \text{Difference: } D_n = C_n - C_0 \text{ (for } x_n = x_0)$$
$$C_n = C_0 - 5n/13 \qquad \text{Error: } E_n = D_n(x) - D_n(0)$$
$$A_n = \sqrt{B_n^2 + C_n^2}$$

For $n = 7$,
$B_7 = 46.15385 + 84/13 = 52.61539 \pm 0.00001$
$C_7 = 110.76923 - 35/13 = 108.07692 \pm 0.00001$
$A_7 = 120.20399 \pm 0.00001$

The amount of error for different cast locations and with interocclusal records of different thicknesses (x) is shown in Tables IV and V.

From these results, certain patterns can be recognized and a formula pertaining to the articulation of casts which represent natural dentitions evolved. If the hinge axis interocclusal records are made at relatively small degrees of opening (not more than 5 mm.) and if the maxillary cast is not far from its proper position relative to the hinge axis (not more than 5 mm.), the maximum error induced by closing the articulator to occlusal contact will be the number of millimeters of articulator closure (from the vertical dimension at which the lower cast was mounted) multiplied by the error in the hinge axis location (in millimeters) and divided by 100. For example, if the hinge axis has been improperly located by as much as 3 mm. and if the thickness of the mounting record is 3 mm., the error at the occluding position of the casts (anteroposteriorly) will be about 0.09 mm., or less than 1/250 inch. It is possible to compute potential errors for other situations in which the vertical dimension on the articulator is either increased or decreased.

Interpretation of Table II leads to the following conclusions. If the hinge position has been improperly located superior to line *A* (Fig. 4) and the articulator is closed after the lower cast has been mounted, the occlusal contact of the mandibular cast with the maxillary cast will be in protrusion with premature contact on the anterior teeth. If the hinge axis has been improperly located inferior to line *A* and the same conditions prevail, at occlusal contact the mandibular cast will be in retrusion and premature posterior contact will be present. If the hinge position was mislocated on line *A* anterior to *P*, there will be a slight retrusion. If the mislocation was on line *A* but posterior to *P*, there will be a slight protrusion when the casts are occluded.

Unfortunately, there is no simple way to determine if the maxillary cast has been improperly related to the axis of the hinge articulator. The only way one can be relatively certain that errors due to malpositioning of the maxillary cast on the articulator have been avoided is to use a hinge-bow, a suitable articulator, and a precise technique. If a conventional face-bow is used, the errors introduced will be in the magnitude of those shown in Table V. If the casts are arbitrarily oriented on an articulator, the occlusal errors resulting from reduction of the vertical dimension will be of a still greater magnitude.

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THE COMPENSATING CURVE FOR COMPLETE DENTURES

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THE OBJECTIVE OF THIS ARTICLE is to clarify the function of the compensating curve of occlusion in dentures and to determine if this function follows sound principles. To simplify the problem, only angles and curves in the sagittal plane are discussed. According to the *Glossary of Prosthodontic Terms,*[1] the compensating curve is defined as: "The anteroposterior and lateral curvature in the alignment of the occlusal surfaces and incisal edges of artificial teeth which is used to develop balanced occlusion." According to the same glossary, balanced occlusion is defined as: "The simultaneous contacting of the upper and lower teeth on the right and left and in the anterior and posterior occlusal areas. This occlusion is developed to prevent a tipping or rotating of the denture bases in relation to the supporting structures. It is thought of primarily in the mouth, but it is arranged and may be observed on articulators."

In order to obtain a smooth, balanced occlusion, the compensating curve must be in harmony with the other factors of occlusion. This relationship is expressed in Hanau's Quint.[2] It is expressed even more clearly by Thielemann's formula of occlusion.[3] The formula is usually expressed as:

$$\frac{K \cdot I}{op \cdot C \cdot ok},$$

where K is the inclination of condylar guidance, I is the inclination of the incisal guidance, C is the height of the cusps, op is the inclination of the plane of orientation, and ok is the prominence of the compensating curve.

Thielemann[3] uses the phrase, "the profound of the compensating curve," which means the distance from the plane of occlusion to the lowest-situated point of the curve. According to Müller,[4] this point is situated between the second bicuspid and the mesiobuccal cusp of the first molar of the lower jaw. Thielemann's formula is an empirical one which indicates the *relation* among the factors of occlusion and does not express precise values. To clarify the exact relation, it is necessary to introduce some new terms.

CUSP PLANE AND CUSP PLANE ANGLE

When the two buccal cusp tips and the highest-situated lingual cusp tip are connected with straight lines, these lines circumscribe a small plane which is called the "cusp plane." Two aligned bicuspids are regarded as one single tooth. The plane

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TABLE I. CUSP INCLINE TABLE

INCLINATION OF CONDYLAR GUIDANCE	10°	20°	30°	40°	50°
Cusp angulation (Σ) of first molar	3°	6°	9°	12°	15°
Cusp angulation (Σ) of second molar	4°	8°	12°	16°	20°
Cusp angulation (Σ) of third molar	5°	10°	15°	20°	25°

The cusp plane is assumed to be situated in, or parallel with, the plane of occlusion.

may have a transverse and a sagittal slope in relation to the plane of occlusion. In this investigation, however, only projections in the sagittal plane are discussed. The connecting line between the buccal cusps indicates the sagittal slope, and the alignment of these lines forms the compensating curve. The inclination of the cusp plane to the plane of occlusion is called the "cusp plane angle."

COMPENSATING CURVE FORMULA

To simplify the understanding of the effect of the compensating curve, the curve will be described as two straight lines with the lowest-situated point between the mandibular second bicuspid and the first molar (Fig. 1). The tips of the incisors, the cuspid, and the cusp plane of the bicuspids are on the line PP_1. The cusp plane of the molars is on the line MM_1. These lines each form an angle with the plane of occlusion. This angle (ω) is identical with the cusp plane angle.

By previously performed calculations of the cusp angulation, as expressed in Table I, the compensating curve is assumed to be a straight line.[5] The angulation

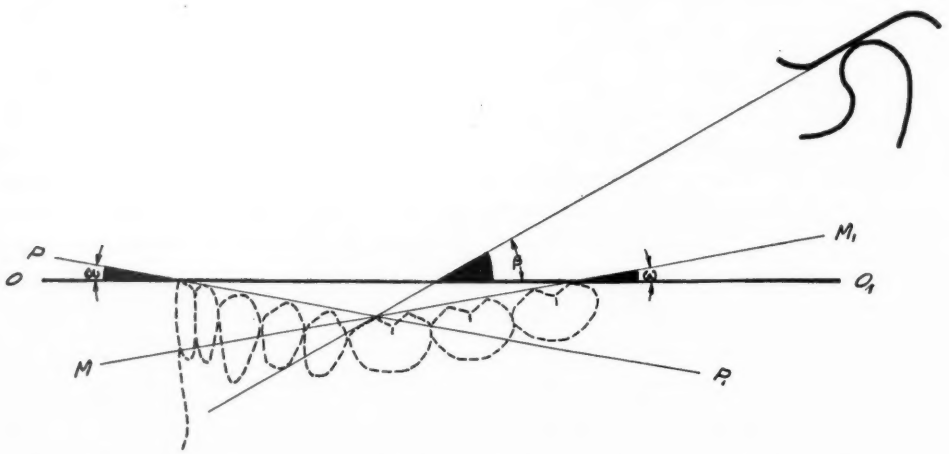

Fig. 1.—The compensating curve is outlined as two straight lines (PP_1 and MM_1). The cusp plane angle is ω. β is the inclination of the condylar guidance.

of the protrusive facets with various condylar guidance inclinations is calculated in relation to the plane of occlusion. On varying the cusp plane angle, the cusp angulation of the protrusive facets has to be altered accordingly to retain the same incline of the facets to the plane of occlusion. The action of the compensating curve is as follows. The cusp angulation (Σ) of the protrusive facets of the molars (calculated in accordance with the cusp incline table) must be reduced with an angle equal to the cusp plane angle (ω). This relation can be expressed by means of the formula:

$$C = \Sigma - \omega,$$

where C is the cusp angulation, Σ is the cusp angulation according to Table I, and ω is the cusp plane angle. This formula is called the "formula for the compensating curve."

The cusp plane angle for the third molar is equal to ω_8 (Fig. 2). The angulation of the protrusive facets based on Table I must be reduced by an angle equal to ω_8. The angulation of the cusp plane of the third molar to the condylar guidance

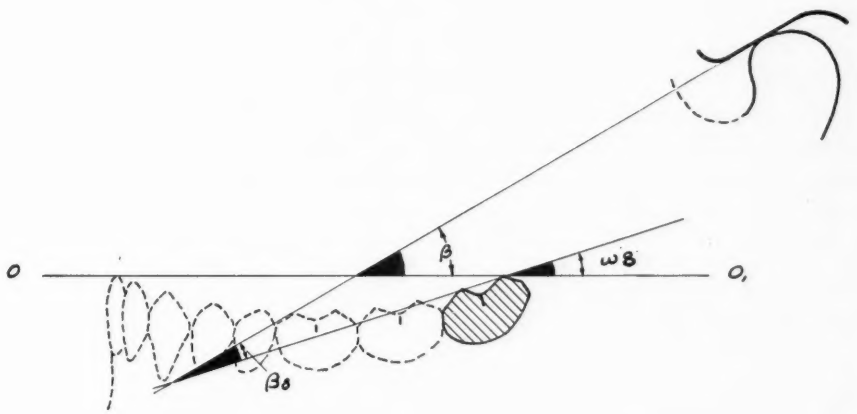

Fig. 2.—The sagittal slope of the third molar in the compensating curve. The cusp plane angle is ω_8. The angle of the cusp plane proportionated to the condylar path is: $\beta_8 = \beta - \omega_8$, where β is the inclination of the condylar guidance.

is: $\beta_8 = \beta - \omega_8$. The corresponding relationship for the second molar involves ω_7 and β_7 (Fig. 3), and for the first molar, ω_6 and β_6 (Fig. 4).

Example.—A patient has a condylar guidance inclination equal to 40 degrees on both sides. Ten-degree posterior teeth have to be used for the construction of complete dentures. How is the compensating curve of occlusion to be formed?

According to the cusp incline table and the formula for the compensating curve, it is possible to calculate the cusp plane angle to obtain a smooth contact for all of the protrusive facets. In accordance with the cusp incline table, the cusp angulation for the mandibular second molar is 16 degrees; however, the cusp

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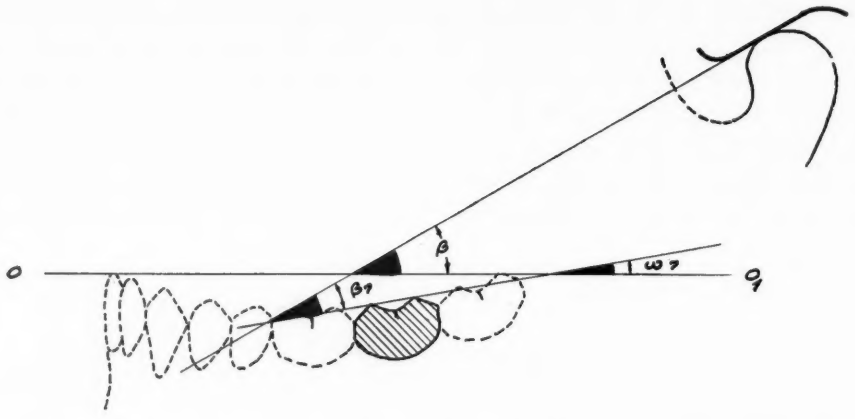

Fig. 3.—The sagittal slope of the second molar in the compensating curve. The cusp plane angle is ω_7. The angle of the cusp plane proportionated to the condylar path is: $\beta_7 = \beta - \omega_7$, where β is the inclination of the condylar guidance.

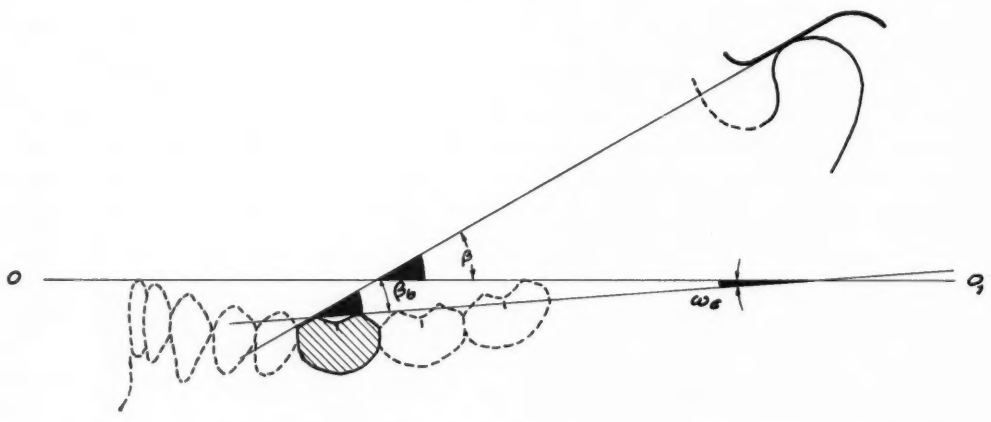

Fig. 4.—The sagittal slope of the first molar in the compensating curve. The cusp plane angle is β_6. The angle of the cusp plane proportionated to the condylar path is: $\beta_6 = \beta - \omega_6$, where β is the inclination of the condylar guidance.

inclination of the posterior teeth is 10 degrees. The cusp plane angle of the second molar in the curve may be calculated by the formula for the compensating curve:

$$C = \Sigma - \omega$$
$$\omega = \Sigma - C$$
$$\omega = 16° - 10°$$
$$\omega = 6°$$

In this example, the cusp plane angle (ω) for the second molar is equal to 6 degrees, which is the difference between the cusp angulation, according to Table I, and the actual cusp angulation of the molar which is used. In the same way, the cusp plane angles (ω) for the first and the third molars are calculated to be 2 and 10 degrees, respectively.

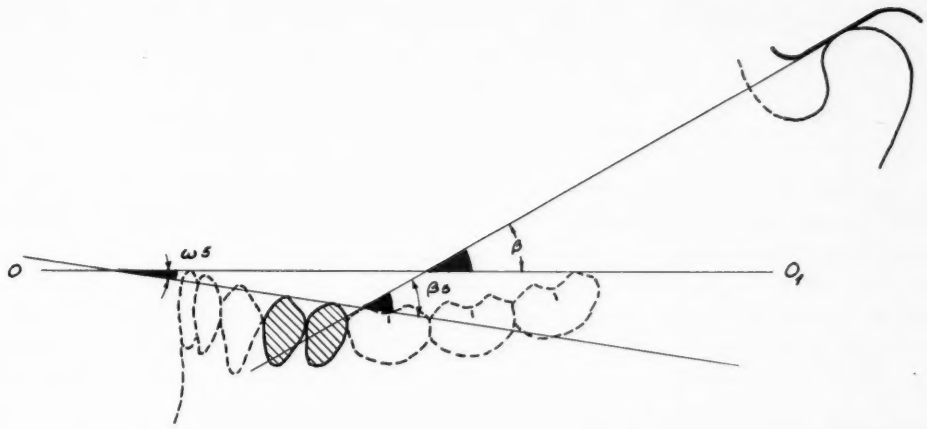

Fig. 5.—The sagittal slope of two aligned bicuspids to the compensating curve. The cusp plane angle is ω_5. The pitch of the cusp plane proportionated to the condylar path is: $\beta_5 = \beta + \omega_5$, where β is the inclination of the condylar guidance.

BICUSPID ARRANGEMENT

The cusp plane angulation of the bicuspids is equal to ω_5 (Fig. 5). The angulation of the bicuspid plane to the condylar guidance is: $\beta_5 = \beta + \omega_5$, which is greater than the inclination of the condylar guidance (β). Therefore, the cusp angulation may be steeper to attain antagonistic contact for protrusive movement. Consequently, *the curve of occlusion decreases the cusp angulation for the molars and increases the cusp angulation of the bicuspids.*

In practice, we do not use high cusps for the bicuspids. In the region of these teeth, therefore, the antagonists lose their contact during protrusive gliding movements. This is also true on the balancing side during lateral movements. The advantages of this arrangement are the possibility of chewing hard food in the bicuspid region and the coincidentally obtained antagonistic contact in the front and in the molar region.

CUSPLESS POSTERIOR TEETH AND THE COMPENSATING CURVE

Prosthodontists have problems concerning the increase in the age of the patients who need prosthetic treatment. The most marked problem is the senile residual ridge in connection with horizontal stress during mastication.

With cuspless posterior teeth, it is possible to attain a minimum of horizontal stresses during gliding movements. The cusp plane angulation of cuspless teeth in the alignment of the curve of occlusion can be calculated. In accordance with the function of the compensating curve, the cusp angulation (Σ) of the molars, as calculated in Table I, is reduced with an angle equal to the size of the cusp plane angle (ω).

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The cusp angulation *(C)* with cuspless teeth equals zero degrees. According to the formula for the compensating curve, the following relationship is obtained:

$$C = \Sigma - \omega$$
$$0° = \Sigma - \omega$$
$$\Sigma = \omega$$

When setting cuspless posterior teeth, therefore, the cusp plane angle must be equal to the cusp angulation according to the cusp incline table. Providing that the inclination of the condylar guidance is known and measured in relation to the plane of occlusion (occlusion rims), cuspless teeth can be arranged in approximately balanced occlusion on a hinge articulator by means of Table I and a protractor.

On an average articulator, the inclination of the condylar guidance is usually 30 degrees. According to the cusp incline table, the slopes of the first and the second molars are, respectively, 9 and 12 degrees. Therefore, setting teeth for complete dentures may be completed on a hinge articulator with the same results as on an average articulator. Standard inclination of condylar guidance gives a standard curve. The effect of Bonwill's triangle[6] and Balkwill's angle[7] on the inclination of the cusp plane of cuspless teeth is of less importance for the balanced occlusion.

SUMMARY AND CONCLUSION

By means of the compensating curve, complete antagonistic contact during protrusive movements can be obtained with lower cusp angulation than is indicated by Table I. The reduction of the cusp angulation is equal to the inclination of the cusp plane in the curve. Consequently, the function of the compensating curve is a reduction of the cusp angulation with an angle equal to the cusp plane angle.

The inclination of the cuspless posterior teeth in the curve of occlusion can be calculated. The cusp plane is regarded as one single protrusive facet and is set up in accordance with the cusp incline table.

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EVALUATION OF REST POSITION AS A GUIDE IN PROSTHETIC TREATMENT

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THE REST POSITION OF THE MANDIBLE is an important clinical entity to the prosthodontist. Its importance lies in the establishment of anterior face height and an ideal interarch space with dentures. Mandibular rest position is generally assumed to be relatively stable throughout life and independent of the teeth. It is further assumed that rest face height should serve as a reliable guide to the restoration of occluded face height with a prosthesis, even when no pre-extraction records are available.

PAST FINDINGS

Many authors have commented on the inactive state of the masticatory musculature and its clinical significance. Tench[1] and Niswonger[2,3] began in the 1930s to attract attention to the significance of rest position. Thompson[4-6] integrated rest position with the basic anatomy and physiology of the parts involved. Thompson and Brodie[7] further integrated rest position with the growth and development of facial structures and, as a result, the concept became more widely accepted.

The acceptance of the concept of the stability of the mandibular rest position is based mainly on the quantitative data presented by Thompson in the early 1940s. Such studies as that of Thompson, however, originated where the interest was remote from the clinical problems of prosthetics. It was not until Atwood[8] in 1956 and Tallgren[9] in 1957 reported longitudinal studies of denture patients that we began to collect adequate evidence concerning the reliability of the concept of rest position as related to complete denture construction. In both of these studies, there was a change in rest face height after the removal of occlusal contacts. In the light of discussion by Brill[10] and Walsh[11] concerning reflex activity of the mandible, the instability of rest position is not entirely unexpected. We must accept the fact that changes occur in the postural position of the mandible after extraction of all the teeth. How this affects denture techniques has yet to be elucidated.

Condensed from a thesis presented in partial fulfillment of the requirements for the degree of Master of Science at Washington University, School of Dentistry, St. Louis, Mo., June, 1959.

The views expressed are those of the authors and in no way reflect the views of any component of the United States Air Force.

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RESTORING THE FUNCTIONAL MECHANISM

The restoration of the functional mechanism of the jaws with complete dentures requires some reliable guide, in addition to clinical judgment. For most individuals, it seems desirable to restore the same functional conditions that existed with the natural dentition. This is important, especially in terms of the occluded face height and the functional space between the teeth. The occluded face height is important because of esthetic considerations, as well as possible prevention of angular cheilosis and temporomandibular joint disorders.

The efficiency of the masticatory musculature is also related to face height. Boos[12] demonstrated that the amount of force an individual can exert with the mandibular musculature is dependent on the amount of jaw opening. There may be situations in which it is desirable to reduce the force an individual can exert by reducing the occluded face height; however, excessive reduction of the face height is undesirable. Thus, there is justification for maintaining the pre-extraction face height with dentures, or at least for making specific alterations in the face height with the teeth in occlusion. Previous studies leave doubt as to whether this can be done without pre-extraction records.

PURPOSE OF THIS STUDY

This study was designed to observe patients with complete dentures in which all of the procedures were in complete support of the concept of rest position. Atwood[8] did not demonstrate a specific approach, in terms of a clinical method, for establishing the vertical dimension of occlusion. Thus, his data cannot be compared to studies where a known clinical procedure was used. Tallgren[9] used esthetics as a primary guide for establishing vertical dimension. This resulted in an excessive increase of the face height with the teeth in occlusion when compared to the pre-extraction record. Data are not available to establish the reliability of rest position as a guide to pre-extraction conditions.

DENTURE CONSTRUCTION

Patients receiving routine denture service at the Washington University School of Dentistry were included in this study. Since facial dimensions after the extraction of teeth and prosthetic treatment were to be compared with facial dimensions prior to extraction of the teeth, subjects with the greatest possible occlusal support were selected. No persons with an appreciable decrease in vertical dimension due to the loss of teeth were accepted. Patients requiring immediate complete upper dentures against natural lower teeth were excluded, so that no pre-extraction guide in the form of tooth contact would be available. No attention was paid to the occlusion or jaw relationship.

Complete upper and lower dentures were constructed by students under the supervision of the prosthetic department staff. The impressions were made, using individual trays with functionally established borders. Corrective washes were made in plaster for the upper impression and zinc oxide and eugenol impression paste for the lower impression. A closed-mouth impression technique was employed on the

lower arch after the vertical dimension was established. The principal factor utilized for establishing the vertical dimension of occlusion was the registration of 2 to 4 mm. of interocclusal distance between wax occlusion rims. Rest position of the mandible was established by having the patient say *m*, and this position was checked against the position of the mandible after swallowing. Measurements were made from the nose to the chin. Centric and eccentric relations were registered with an extraoral Gothic arch (needle-point) tracing. These registrations were recorded and transferred to the articulator with plaster interocclusal records. Dentures were constructed using heat-cured acrylic resin. All dentures were remounted on the articulator, and the balanced occlusion was perfected by selective grinding and milling.

ROENTGEN EXPOSURE

Since several roentgenographic exposures were necessary, consideration of the amount of radiation the patients received appeared warranted. The Broadbent-Bolton roentgen cephalometric unit requires a 60-inch target-film distance, and the exposure time for one roentgenogram is 0.5 second at 70 KVP and 20 Ma. with 2.5 mm. of aluminum filtration. Therefore, the patients received a calculated roentgen (r) value of 0.015 r per exposure.[13] A patient having a 1.0-second intraoral roentgenogram made with an ordinary dental roentgen unit with a 8-inch target-film distance, 65 KVP, and 10 Ma. receives a calculated dose of 0.78 r per exposure. Therefore, the cephalometric roentgenographic procedure would require 52 roentgenograms to be equal in exposure to one intraoral exposure.

ROENTGENOGRAPHIC TECHNIQUE

The technique for obtaining rest position while the patient was in the cephalostat was the same as that used during denture construction. At each sitting, the subject remained in the cephalostat until all exposures had been made. The midline-to-film distance was controlled between sittings to avoid magnification errors.

The following roentgenograms were made of each subject: (1) before extraction of the teeth, two exposures in mandibular rest position and one with the teeth in centric occlusion, (2) after completion of the dentures, two exposures of mandibular rest position with the dentures in the mouth and two with the dentures out, and (3) finally, one exposure with the dentures in the mouth and the teeth in occlusion.

Tracings were made from each film and the measurements from nasion to gnathion were made with dividers and transferred to a vernier millimeter scale. Nasion was considered to be the most anterior point of the nasofrontal suture as seen from norma lateralis, and gnathion as a point on the bony chin determined by bisecting the angle formed by the facial and mandibular planes.[14] Morphologic face height was taken as the distance between the craniometric reference points nasion and gnathion when the upper and lower teeth were occluded. This definition also applies to the roentgenometric assessment by means of corresponding roentgen cephalometric measurements. The face height at rest was determined by measuring from nasion to gnathion when the patient had assumed a rest or relaxed

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position of the mandible. The interocclusal distance was determined by computing the difference between the morphologic face height and face height at rest.

RESULTS

Observations were made on 10 patients for whom complete dentures were constructed. All dentures were considered clinically successful.

When comparing the pre-extraction morphologic (occluded) face height with the morphologic face height after prosthetic treatment, all patients had reduced face height except patient 2. The reduction in morphologic face height varied from 0.3 mm. (0.2 per cent) to 5.9 mm. (4.4 per cent), with the over-all mean reduction

TABLE I. MORPHOLOGIC FACE HEIGHT*

PATIENT	BEFORE EXTRACTION	AFTER PROSTHETIC TREATMENT
1	130.7	130.2
2	116.8	122.0
3	114.6	113.0
4	106.9	106.6
5	123.1	120.0
6	118.6	116.5
7	134.2	128.3
8	111.1	110.6
9	105.6	105.1
10	137.2	132.0
Mean	119.8	118.4

*Measurements in millimeters from nasion to gnathion with teeth occluded.

being 1.4 mm. (Table I). The morphologic face height was increased with the prosthesis 5.2 mm. (4.4 per cent) for patient 2.

The interocclusal distance was increased in all patients after prosthetic treatment, with the exception of patient 8 (Table II). This general increase in interocclusal distance ranged from 0.1 mm. (2.3 per cent) to 3.3 mm. (550 per cent). In patient 8, the interocclusal space was reduced 1.5 mm. (32 per cent). Patient 2 had an interocclusal distance of 2.1 mm., even though the morphologic face height was increased beyond the pre-extraction interocclusal distance (Table I). Patients 1, 4, 8, and 9, whose morphologic face height before and after prosthetic treatment differed 0.5 mm. or less (Table I), had an interocclusal distance that ranged from a 32 per cent reduction to a 550 per cent increase.

When comparing the pre-extraction rest face height with the rest face height after prosthetic treatment (dentures in the mouth), a difference ranging from −3.5 mm. to +5.6 mm. was observed (Table III). The mean difference was −0.11 mm. A similar comparison without the dentures in the mouth showed a variation from −6.6 to +0.8 mm. The mean difference with this reference was −2.65, which was statistically significant at the 1.0 per cent level ($t = 3.44$).

DISCUSSION

Morphologic face height with the dentures showed considerable variation, and 3 out of the 10 patients showed a difference of more than 5 mm. in comparison with

TABLE II. INTEROCCLUSAL DISTANCE*

PATIENT	BEFORE EXTRACTION	AFTER PROSTHETIC TREATMENT
1	2.1	4.1
2	1.7	2.1
3	4.4	4.5
4	2.5	3.2
5	1.4	4.6
6	0.3	1.0
7	0.9	3.7
8	4.6	3.1
9	0.6	3.9
10	3.4	5.1
Mean	2.19	3.53

*Measurements in millimeters of the difference between rest face height and morphologic face height before extraction and after prosthetic treatment.

the pre-extraction morphologic face height. If it is possible to err this much in establishing morphologic face height with dentures, as based on rest position, the rest position of the mandible is not a reliable guide for this procedure. Tallgren[9] demonstrated that nearly all subjects had an increased morphologic face height with dentures when esthetics was used as a primary guide. We observed only 1 patient who had an increased morphologic face height using rest position as a guide (Table I). Thus, neither esthetics nor rest position serves well as a guide to the pre-extraction morphologic face height.

There is a general reduction in face height at rest after the removal of occlusal contacts (Table III). When comparing the rest face height before extraction of

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TABLE III. REST FACE HEIGHT*

PATIENT	A BEFORE EXTRACTION	B WITH DENTURES	C WITHOUT DENTURES	DIFFERENCE BETWEEN A AND C
1	132.8	134.3	130.8	−2.0
2	118.5	124.1	116.5	−2.0
3	119.0	117.5	115.2	−3.8
4	109.4	109.8	108.9	−0.5
5	124.5	124.6	122.8	−1.7
6	118.9	117.5	112.3	−6.6
7	135.1	132.0	129.2	−5.9
8	115.7	113.7	112.0	−3.7
9	106.2	109.0	107.0	+0.8
10	140.6	137.1	139.5	−1.1
Mean	122.07	121.96	119.42	−2.65

*Average of two measurements in millimeters from nasion to gnathion with patient assuming rest position.

the teeth and after prosthetic treatment (without dentures in the mouth), a mean difference of 2.65 ± 0.77 mm. was observed. This was significant at the 1.0 per cent level ($t = 3.44$).

This variation in rest face height has been observed by others. Tallgren[9] found a significant (1.0 per cent level) reduction in rest face height after extraction of the teeth in a longitudinal study of 32 patients. The mean difference observed was −1.40 ± 0.43 mm. Atwood[8] points to the loss of the periodontal receptors as the principal influence on this postural change in the mandibular position. The periodontal receptors, lost as a result of the extraction of teeth, are thought to influence the masticatory reflex.[10,11] The postural reflex of the mandible is also closely associated with neural pathways of the masticatory reflex.[11] Thus, the loss of these nerve endings may hamper the orientation of the mandible. This could account for the instability of rest position seen in Table III.

An arbitrary interocclusal distance was selected by the dentist without knowledge of the pre-extraction record. This arbitrary interocclusal distance was based on average determinations from the work of such investigators as Niswonger[3] and Thompson.[4] This earlier work was not designed, however, to show the influence of occlusal contacts but merely indicated the relative, constant nature of rest position and gave average values for the interocclusal distance.

Many dentists adopted the average interocclusal distance as one to be used in their complete denture technique. Landa[15] warned against this procedure on the

basis that the range of the interocclusal distance may be quite large. This fact is quite evident in this study. The standard deviation was 1.34 mm. with a mean of 2.19 mm. Thus, the mean plus or minus one standard deviation would give a minimum range of 0.8 mm. to 3.5 mm. to be considered in estimating the interocclusal space of an individual. In the work of Tallgren,[9] the mean plus or minus one standard deviation gave a range of 0.2 mm. to 4.8 mm. It is this range in which we can predict approximately two-thirds of the patients will fall.

To illustrate further the fallacy of arbitrarily selecting an interocclusal distance for the patient, Tallgren[9] observed that 19 per cent of 165 patients with normal occlusion had less than 1.0 mm. of interocclusal distance. Often, this minimum interocclusal distance is not given proper consideration. It is not unexpected when we observe patient 9 and note an increase of 550 per cent in interocclusal distance between the stages before extraction and after prosthetic treatment (Table II).

There seems to be an individual, adaptive, neuromuscular mechanism accounting for the change in rest face height after a change in morphologic face height with dentures. This can be seen in patient 2 (Table I). The morphologic face height for this patient was restored to a height greater than the pre-extraction rest face height. This completely obliterated the pre-extraction interocclusal distance. Thus, an adjustment mechanism must be operating or no interocclusal distance would have been registered in this instance. The presence of baseplates and occlusion rims may cause registration of a rest face height much greater than that with nothing in the mouth. It is a matter of clinical judgment as to how much the baseplates and occlusion rims influence the rest position.

Of major significance is the fact that many patients with well-formed ridges, prior to any resorption, often have little space for the setting of posterior teeth. If the morphologic face height is reduced unintentionally as it was for patients 7 and 10 (Table I), the existing space problem would be much worse.

SUMMARY

Studies were made to determine the value of rest position in establishing pre-extraction face height with a prosthesis when no pre-extraction records were available. Patients were selected who furnished an acceptable pre-extraction record in terms of the vertical dimension of occlusion. Records were made before extraction and after prosthetic treatment with a Broadbent-Bolton roentgen unit. Rest observations were made both with and without dentures in the mouth. Measurements were made of morphologic (occluded) face height, rest face height, and the interocclusal distance.

The results revealed an instability of rest position which resulted in discrepancies in the restoration of the pre-extraction vertical dimension with the prosthesis. This difference in pre-extraction vertical dimension and that restored with the prosthesis was of such magnitude in 3 of the 10 patients that rest position was concluded to be a poor guide for establishing the pre-extraction vertical dimension. Because of this fact, pre-extraction records are deemed mandatory.

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TOOTH PLACEMENT AND BASE CONTOUR IN DENTURE CONSTRUCTION

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PROSTHESIS IS THE ADDITION to the human body of some artificial part. This definition indicates that a prosthetic restoration should function and reproduce the lost part as closely as possible. In many instances, this result is not obtainable. However, the possibility of meeting these qualifications in complete denture construction exists to a greater extent than with other prostheses.

Vast improvements have been made in denture materials and techniques. But, Nature's method of tooth placement and contour of tissues results in more esthetic appearance and more comfort and satisfaction to the denture patient.

Immediate dentures are usually superior to delayed dentures because the anterior teeth can be replaced more accurately. However, most dentures are constructed without pre-extraction records and with only the questionable memory of the patient, old dentures, and our own experience to guide us.

Many dentists and laboratory technicians place both anterior and posterior teeth over the crest of the residual ridges. This arrangement produces good results in the posterior segments but almost always places the anterior teeth too far back in relation to the position of the natural teeth. This improper position results in lack of proper support for both upper and lower lips and causes a definitely altered appearance of the lower third of the face.

A change in facial contour is one of the main objections of the average patient to complete dentures. Many prospective denture patients retain infected and defective teeth which are injurious to their health and cause loss of supporting tissue for this reason. If the apprehension associated with a change in appearance can be eliminated, patients may accept dentures before the destruction of supporting tissue presents a serious problem to the dentist (Fig. 1).

ANATOMIC LANDMARKS

The surface anatomy of the oral tissues affords clues that help locate the proper position of the anterior teeth on the denture base. The first landmark of importance in the anterior region of the maxillary process is the incisive papilla.

The incisive papilla is an elevation of soft tissue covering the incisive foramen, a funnel-shaped opening in the midline of the palate. The papilla is located immediately behind the mesial surfaces of the two central incisors. For some time after

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the teeth are removed, the incisive papilla remains in its original position. However, because of progressive bone loss, especially that of the labial plate, an illusion is produced and the papilla seems to move forward. The foramen under the papilla cannot move, but its opening can be altered, which causes this apparent change (Fig. 2).

A line drawn through the middle of the incisive papilla in an anteroposterior direction passes through the contact point of the mesial surfaces of the two upper central incisors. A line drawn at right angles to this line and bisecting the papilla

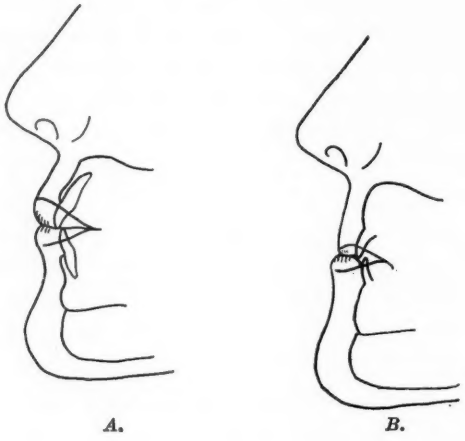

Fig. 1.—Tracings from cephalometric roentgenograms. *A*, Natural lip and tooth displacement. *B*, The changes caused by incorrect tooth placement.

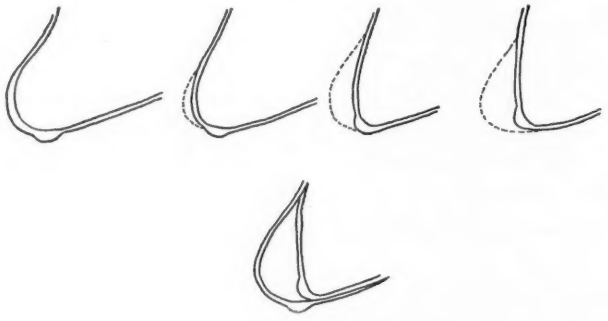

Fig. 2.—An apparent change in the position of the incisive papilla results from the loss of the labial plate.

in the opposite direction will, in many instances, touch the curved lingual surface of the central incisors at the gingival line. In some mouths, the lingual surfaces of the central incisors will be slightly anterior to this position (Fig. 3).

In order to place the central incisors as close as possible to their original position, the average diameter of the central incisor at the gingival line was

determined. The range of measurements was from 6.8 mm. to 8.6 mm., with an average of 7.7 mm. Since the central incisors are often slightly anterior to the base line selected, a measurement of 8.0 mm. is used.

MARKING THE CAST

Before a trial base is made, the upper edentulous cast is marked as a guide for tooth position. The papilla is bisected with a line in both directions, and the anteroposterior line is continued forward to mark the cast outside of the reflection. This line shows the position of the mesial surfaces of the upper central incisors. A line is made on the base of the cast 8.0 mm. anterior to the bisecting point on the papilla. This line locates the labial surfaces of the two central incisors for the *average* patient. However, 8.0 mm. is an average measurement and only a starting position for the placement of the central incisors. This position may be altered in an anterior or posterior direction to meet the requirements of the individual patient.

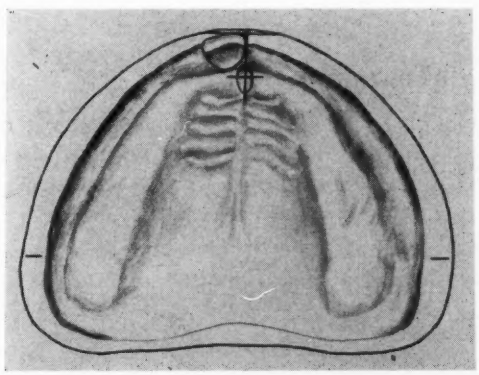

Fig. 3.—Lines are drawn on the cast to locate the position of the labial and mesial surfaces of the central incisors and the second molars.

VERTICAL INCLINATION AND LENGTH

The six upper anterior teeth not only position the upper lip, but their incisal edges position the lower lip by making contact with the lingual half of its vermilion border in both rest and occluded positions. Therefore, the six upper anterior teeth must be arranged to accomplish this function.

In normal relationship, when the horizontal and vertical overlaps are not over 3.0 mm., the labial surfaces of the upper central incisors are usually parallel to the profile or inclined slightly inward at the incisal edge. A phonetic test can be made with the pronunciation of the letters *f* and *v* to determine if this position is correct. The incisal edges of the upper teeth make a firm contact with the lower lip at the correct point. This procedure is correct *except* for a patient with a true mandibular protrusion.

The curvature of the upper anterior teeth is observed by gently raising the upper lip. An incisal edge of an upper anterior tooth that does not make contact with the lingual half of the vermilion border of the lower lip should be moved forward. Any incisal edge that makes contact anteriorly to the lingual half of the vermilion border of the lower lip should be moved back. When the lips are slightly parted, the line of the incisal edges should be parallel to the curve of the lower lip as it rises from the median line to the corners of the mouth.

POSTERIOR TOOTH SELECTION

The central incisors of many complete dentures are placed directly above and often behind the incisive papilla. This arrangement causes the posterior teeth to be placed distal to their original position. Thus, the artificial second molar occupies the position of the natural third molar directly over the tuberosity. To select the proper size of posterior teeth, a mark is made on the base of the upper cast opposite the anterior edge of the tuberosity. Then, a measurement is made from this mark to the distal surface of the cuspid to indicate the available space for posterior teeth.

LOWER ANTERIOR TOOTH POSITION

The lower anterior teeth are placed over the labial half of the lower residual ridge with the vertical inclination at right angles to the lower border of the mandible. The incisal edge is even with or slightly higher than the lower lip at rest.

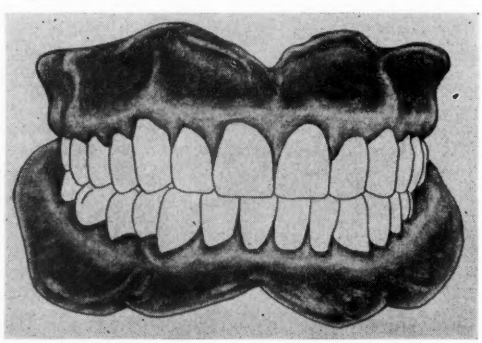

Fig. 4.—The correct contour of the labial and buccal denture flanges is essential for esthetic appearance, comfort, retention, and stability.

This procedure places the artificial teeth in close approximation with the position of the natural teeth. After the six upper and six lower anterior teeth have been arranged, the temporary (wax trial) bases are placed in the mouth and the teeth are adjusted to produce the correct horizontal and vertical overlap for the individual patient.

ESTABLISHING THE OCCLUSAL PLANE

The triangular retromolar pads are outlined in pencil on the lower edentulous cast, and marks are made on the cast opposite the apex of the triangle. The pads are bisected in an anteroposterior direction, and marks are also made on the cast

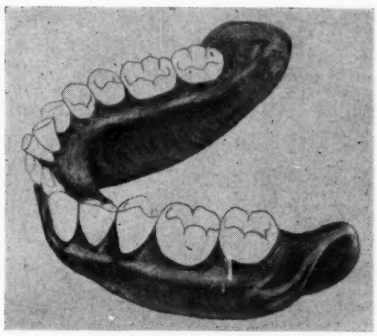

Fig. 5.—The correct contour of the denture base of the lower denture is essential for the denture to be successful.

opposite these points. The first mark indicates the position of the distal surface of the second molar, and the second mark indicates the height of the occlusal plane. The occlusal plane to retromolar pad relationship may be observed on any lower cast of natural teeth where the third molars are missing. The older method of placing the occlusal plane at a point midway between the upper and lower edentulous ridges often places it too high in relation to the lower ridge. The additional leverage thus created usually causes discomfort to the denture patient and instability of the denture.

NATURAL CONTOUR OF DENTURE BASES

The placement of teeth in their natural position is not the only problem in constructing a denture. The denture base also should have the same anatomic form as that of the tissue replaced and covered. The study of well-made casts with a full complement of natural teeth and the adjacent tissue gives the necessary information to simulate Nature. All mouths are similar anatomically and vary only in degree as to the height of a prominence or depth of a fossa.

UPPER DENTURE CONTOUR

The six upper anterior teeth, incisive fossa, cuspid eminences, and gingival bulge support the upper lip in its normal position (Fig. 4). The vermilion border is the proper size, the philtrum is well defined, and the upper lip is usually concave in profile. In the average denture, the six anterior teeth are usually placed too far back in the mouth, there is no incisive fossa, and although the cuspid eminences are often present, they are usually obliterated by a gingival bulge that terminates at

the upper border of the denture. These errors result in a thin vermilion border, absence of a philtrum, and a longer than normal upper lip which may have a convex profile.

Distal to the cuspid eminence and above the bicuspids is the canine fossa. This fossa allows the bicuspids and the gingival bulge above these teeth to support the corner of the mouth. Although seldom reproduced in the average denture, this depression is of real importance if normal facial expression is to be retained. Even when dentures are constructed with the correct vertical dimension of occlusion, the corners of the mouth often turn down. To avoid this condition, bulk has been added to cuspid eminences and extended to the bicuspid area. This addition of material in this region results only in an unnatural appearance and does nothing but accentuate the problem. Correct contouring of the denture base in the anterior and bicuspid region will do much to obtain patient confidence in maintaining the previous natural appearance.

The malar process above the molars is a convex bulge extending from the gingivae of the molars to the tissue of the reflection. This process is especially prominent above the distal half of the second molar, supports the buccal tissue, and when duplicated on a denture, prevents most cheek biting. Too frequently, the average denture is concave rather than convex in this region, and the tissue is supported only by the buccal surfaces of the molars. The lack of support causes distress to the patient because of cheek biting.

A gingival bulge is present above all posterior teeth on the palatal surface. The bulge is slight in the bicuspid region but becomes more prominent near the second molar. Because the bulge is a normal contour, it should be replaced on a denture.

The rugae and incisive papilla should be reproduced in natural shape and position in the anterior portion of the palate. Correct reproduction of form with proper placement of the anterior teeth reduces phonetic problems and facilitates removal of food particles from the palate. The inability of patients to enunciate clearly is one of the main difficulties with artificial teeth. On many dentures, the anterior teeth, instead of being in front of the papilla, are positioned directly below and sometimes behind this important landmark, thus creating a definite speech problem. Correct placement of teeth reduces this problem to a minimum.

LOWER DENTURE-BASE CONTOUR

A small gingival bulge exists below the lower six natural anterior teeth, and the rest of the labial surface is concave (Fig. 5). This contour supports the lower lip and allows the tissue of the reflection to seal the anterior border of the denture. The labial bulge of the average denture extends from the gingivae to the lower border, making the entire surface convex. This causes an unnatural fullness of the lower lip and increases the difficulty of denture retention. The gingival bulge is also present in the bicuspid and molar region and is most prominent below the first and second molars. Here, the bulge forms a natural food table and, in conjunction with the malar process, holds the buccal tissue away from the teeth and prevents cheek biting. The surface below the bulge is concave to the denture border, which

allows the border to be sealed by the buccal tissues. In the ordinary denture, this surface is usually concave from the gingival margin to the denture border, which causes the teeth to be the only support. This results in discomfort because of cheek biting and accumulation of food during mastication.

A gingival bulge is also present on the lingual surface opposite the bicuspids and molars. However, the bulge is slight near the bicuspids and becomes thicker near the molars. The denture surface is concave from this bulge to the lower lingual border, which allows more freedom for the base of the tongue and provides a better border seal. The gingival bulge can be exaggerated in size when there has been a great loss of the residual ridge and supporting tissues. Thus, the tongue can rest on this rounded surface and help stabilize the lower denture. This surface on most dentures is convex from the teeth to the border, which limits tongue space and reduces denture retention.

Normal contour of both upper and lower dentures is possible only if all available supporting surfaces are covered by the denture base and the borders are in contact with the limiting tissues. In other words, an underextended denture cannot be correctly contoured.

OCCLUSION RIM CONTOUR

Since the correct vertical dimension can be determined only with properly fitted occlusion rims, all landmarks for placing teeth may be used to contour the rims. Thus, except for vertical height, the wax rims are almost completely shaped before they are placed in the mouth. Thereby, time and guesswork are reduced to a minimum.

CONCLUSIONS

Denture patients cannot appear natural to themselves or to others, neither can they be blamed for delaying the loss of their teeth, when dentists fail to duplicate original conditions. Improvements in abnormal conditions can be made, but until we understand and can reproduce normal conditions, we have much to learn. The problem of esthetics in denture construction has been partially solved by characterization of the teeth and denture base, but the full possibilities cannot be realized until we learn to place teeth in their normal, natural positions.

Normal contour of the soft tissues can be reproduced in the denture base by study of the mouth or of casts made from mouths with the teeth present. This reproduction results in dentures with better retention and stability, eliminates cheek biting, and gives natural food tables to prevent packing of food on the buccal surfaces. A normal contour allows more space for the tongue, more phonetic production of sounds, correct lip position, and a desirable upturn of the corners of the mouth.

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SALIVA AND DENTURE RETENTION

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DISCUSSIONS OF RETENTION of the complete upper denture have stressed such factors as (1) reduced atmospheric pressure,[1-3] (2) adhesion, (3) the cohesion, surface tension,[2,4-6] and viscosity[4,6-8] of the layer of fluid between the denture and the mucosa, (4) the shape and weight of the denture, (5) the contact between the polished surface and lips and cheeks,[9] (6) material,[10] (7) occlusion, and (8) articulation. Opinions still differ on the relative significance of these factors, but reduced atmospheric pressure and adhesion are widely accepted as the most important factors.

Schulze[2] studied the problem of retention and performed experiments to show that the thickness of the fluid between two plane surfaces plays a significant role. However, he also found that the plates adhered to one another much better when the intermediate layer was saliva rather than water. Schulze suggested that the difference in retention depends on the difference in the thickness of the fluid, since the lower surface tension of the saliva will press the saliva to a thinner layer than water. He also realized, however, that the difference in viscosity might be responsible for the better adhesion. He states that ". . . the adhesion appears to be better when the saliva is thick than when it is watery."

Schulze also claimed that the retention decreased in proportion to the surface tension of the layer of fluid between the denture and the palate. Östlund,[6] who used an artificial jaw and a denture plate of chrome-cobalt, found that adhesion between these two elements decreased with the surface tension of the intermediate fluid. Stanitz,[5] on pure theoretic grounds, declared that even if surface tension is a retentive factor, it is of little importance.

Cedervärn[4] paid attention to the importance of viscosity in the retention of dentures. Although he suggested that this factor might be of importance in denture retention, he wrote that he could not demonstrate any such influence.

Östlund[8] showed that the adhesion between two plane surfaces moistened with a given fluid varies with the viscosity of the fluid. Plates were mounted in an apparatus with a spring balance which made it possible to measure the traction necessary to draw the plates apart. Östlund also studied the secretion from the palatine glands. He showed that the secretion varied with age and sex and that pressure of the denture against the glandular ducts obstructed secretion, with final destruction of the glands. No attempts were made to determine the strength of retention in vivo. Jordt[7] also found viscosity to be an important factor in retention in vitro.

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Fig. 1.—Casts from the same individual show the successive *decrease* of the secretion from palatine glands after administration of methyl scopolamine nitrate.

Fig. 2.—Casts from the same individual show the successive *increase* of the secretion from palatine glands after administration of neostigmine bromide.

In an attempt to confirm the importance of the viscosity of the saliva in the retention found in laboratory studies of a denture, it was decided to carry out some retention experiments in vivo in which the mucous secretion of the same person was inhibited and stimulated. Östlund and Åkesson[11] showed that secretion of mucin from the palatine glands can be inhibited considerably by submucous injection of methyl scopolamine nitrate (Skopyl) (Fig. 1) and stimulated by oral administration of m-dimethylcarbamoxyphenyl trimethyl ammonium bromide (neostigmine bromide) (Fig. 2). Therefore, measurment of the retention of the denture in the mouth after administration of these two drugs should demonstrate any correlation between the secretion from the palatine glands and the retention of a complete denture.

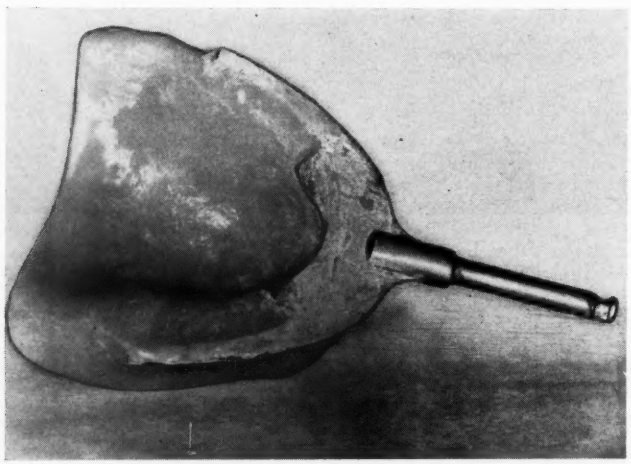

Fig. 3.—An acrylic resin denture base was used to test retention.

MATERIAL AND METHOD

Ten edentulous patients (7 men and 3 women) were selected. The residual ridges of these patients were without undercuts.

Alginate impressions were made without displacement of the soft tissue. Acrylic resin denture bases were made on the stone casts in the following manner.

After outlining the denture base on the cast in pencil, a single layer of moistened asbestos was cut to the shape of the ridge and trimmed over the cast. The base of the cast was trimmed so that a horizontal margin about 2 mm. wide extended beyond the layer of asbestos to support a matrix. A strip of asbestos was wound around the cast, and low-fusing metal was poured into the mold obtained until the ridge was just covered. After removal of the asbestos, the matrix thus secured was trimmed to remove undercuts. The cast and the metal matrix were lined with tin foil, and cold-cure acrylic resin was pressed between the mold and the cast. Thus, an acrylic resin base was obtained which was provided with a lever extending about 35 mm. from the ridge (Fig. 3).

The denture base was placed into the mouth, and the pull necessary to tip the base from the posterior part of the palate was measured by using a spring balance applied in a cranial direction (Fig. 4).

The patient received 0.4 ml. methyl scopolamine nitrate subcutaneously in the fornix vestibulum, and 30 minutes later twenty measurements were made of the retention by the technique described. In order to avoid the possibility of a completely dry mouth influencing the adhesion of the base to the mucosa, the base was moistened with water before it was placed into the mouth.

The following day the patient was given two tablets of neostigmine bromide; 60 minutes after this administration, twenty measurements were made of the retention.

Retention was measured in this way for several reasons. Earlier workers who measured retention directly in the mouth applied the traction to the middle of the palate and pulled the denture base caudally. Although measurement of retention in this way may appear satisfactory, it has some inherent sources of error, especially if the purpose of the investigation is to assess the role of the saliva in retention. For instance, on application of the traction in the middle of the denture base, the surrounding soft tissues of the lip and cheeks will act as a piston,

Fig. 4.—A spring balance determines the force necessary to tip the denture base.

this effect increasing with the thickness of the vestibular plate. Another source of error is the difficulty immobilizing the patient's head. Any changes in position of the head during measurement alter the direction and length of the traction.

These sources of error have not been eliminated by my method, but they have been reduced. It is easier to fix the head against movement in the cranial direction, measurement with the spring balance is facilitated by pulling upward instead of downward, and the suction effect is decreased by rotation of the denture base in the mouth.

RESULTS

The retention recorded after injection of methyl scopolamine nitrate differed considerably from that noted after administration of 2 neostigmine bromide tablets (15 mg.). The increase in retention varied from 57 to 150 per cent (Table I). It was so marked that statistical analysis must be regarded as superfluous. It may be concluded that secretion from the palatine glands in the region covered by the base of a complete upper denture is of great importance for adhesion of the prosthesis. This does not, of course, imply that other factors such as the area of the basal seat, difference in level between the palate and the ridge, etc., need not be considered. However, the number of patients was not large enough to permit analysis of the significance of such factors.

TABLE I

PATIENT	SEX	AGE	RETENTION (GM.)				INCREASE OF RETENTION (%): METHYL SCOPOLAMINE NITRATE/ NEOSTIGMINE BROMIDE
			0.4 ML. METHYL SCOPOLAMINE NITRATE		2 TABLETS NEOSTIGMINE BROMIDE		
			MEAN ± S.E.	S.D.	MEAN ± S.E.	S.D.	
E.G.	F	35	35.8 ± 1.46	6.6	87.0 ± 1.47	6.6	143
H.P.	M	39	45.2 ± 1.13	5.0	84.5 ± 1.98	8.9	87
G.A.	F	53	52.1 ± 1.68	7.5	104.3 ± 3.03	13.4	100
K.L.	M	46	67.7 ± 1.38	6.2	169.2 ± 3.03	13.5	150
O.P.	M	49	72.3 ± 1.92	8.6	162.7 ± 4.63	20.7	125
B.M.	F	55	75.9 ± 1.36	6.1	144.1 ± 4.12	18.4	90
K.R.	F	35	81.7 ± 1.82	7.7	133.4 ± 2.68	12.0	63
S.H.	F	42	88.6 ± 2.49	11.1	139.4 ± 2.95	3.0	57
J.A.	F	46	98.5 ± 2.51	11.2	159.5 ± 2.75	12.3	62
A.A.	F	53	104.3 ± 3.27	14.6	230.5 ± 10.81	48.3	121

DISCUSSION

Saliva has been used in experimental laboratory studies, but little information is available about the conditions under which this saliva was taken from the mouth and how the viscosity was measured. In those investigations in which the viscosity was studied, the apparatus may have broken down the mucin molecules or the interval between the collection of the saliva and measurement of its viscosity may

have been long enough to permit enzymatic destruction of the mucin. Both mechanical and enzymatic destruction rapidly reduce the viscosity of the saliva almost to that of water. Also, the surface tension of saliva is lower than that of water, which means that the viscosity must be of greater significance than suggested by experiments, and the retentive force decreases in proportion as the surface tension of the intermediate film is lowered.

Another reason why the importance of the viscosity of the saliva has not been fully realized is that in laboratory studies use has always been made of mixed saliva. The secretion from the palatine glands is purely mucous, so that the film of fluid between the palate and the denture base is normally fairly viscous.

SUMMARY AND CONCLUSION

Observations made in experiments in vivo in which salivary secretion was stimulated and inhibited showed that the retention of the complete upper denture is dependent to a considerable extent on the rate of secretion of the palatine glands.

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RESILIENT LINERS FOR DENTURES

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Resilient liners for dentures are used with the hope of minimizing pressure and reducing trauma to the supporting tissues without sacrificing contact. Some of the suggested indications are (1) bony ridges with thin, nonresilient soft tissue coverage, (2) persistent denture-sore mouth, (3) knife-edge ridges resulting from marked resorption of the alveolar process, (4) ridges with tissue undercuts where additional operation is contraindicated, (5) relief for maxillary tori or other heavy bony prominences, (6) prosthetic restorations for congenital or acquired oral defects, and (7) stabilizing registration bases for jaw relation records.

The self-curing, soft lining materials have been used in temporary relining applied directly in the mouth, to condition tissues traumatized by old dentures. This procedure is a compromise with that by which the dentures are left out of the mouth to rest irritated tissues before impressions for new dentures are made.

Various requirements for a successful material of this type have been suggested[1-3]: (1) ease of processing, (2) dimensional stability during and after processing, (3) low water sorption, (4) adequate bond strength to the rigid denture-base resin, (5) high abrasion resistance, (6) permanent resilience, (7) color stability, and (8) no adverse effects on the denture base such as distortion, loss of strength, crazing, or blanching.

Certain clinical requirements also are desirable: (1) no burning or irritation to oral tissues when used directly in the mouth, (2) no bad taste or odor, (3) no staining or discoloration, (4) adequate thickness of the soft liner without weakening of the denture base, and (5) ease of finishing and polishing.

A large number of physical and clinical tests are necessary to evaluate any one material on the basis of these requirements. This is a preliminary study of a number of resilient liners tested for two physical properties: (1) the initial hardness of the liners and (2) the changes in hardness and weight of these materials when stored in water at room temperature.

MATERIALS

The resilient liners were selected from a group of materials that represented variations in chemical composition and types of resins. The materials selected were (1) Flexene, (2) Dura Base, (3) Justi Treatment Reliner, (4) Soft Oryl, (5)

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Soft Line (Amco), (6) Plialite, (7) Verno-Soft, (8) Nelson's Soft Lining, (9) Silyne, and (10) Softline (Kerr). The first five materials are acrylic resin polymers or copolymers of the powder-liquid type processed at room temperature. These materials set either by polymerization of the liquid or by loss of the solvent present in the liquid. Plialite and Verno-Soft are flexible acrylic resin copolymers prepared from a powder and liquid by curing at temperatures between 158° and 212° F. Nelson's Soft Lining is a gel containing a plasticized vinyl polymer plus monomer which is cured at 158° to 212° F. Silyne and Softline are silicone rubber materials and are polymerized from a low to a high molecular weight polymer at room temperature by addition of a catalytic agent.

The various manufactures use different methods to produce a resilient liner. A softer methyl methacrylate polymer may be produced by the addition of an extra catalyst or a transfer agent to the monomer to decrease the molecular weight of the polymer. A more common procedure is the use of ethyl or butyl methacrylate in combination with the methyl methacrylate to produce a soft copolymer. In the powder-liquid types, the powder may be a copolymer and/or the liquid monomer may contain the ethyl methacrylate. This procedure plasticizes the polymer internally and this type of material will remain soft.

Another technique for producing a soft liner is the addition of external plasticizers to the monomer. These materials may be oily liquids such as dibutyl or dioctyl phthalate, or they may be organic solvents such as ethyl alcohol. The oily plasticizers are less soluble in the oral fluids than the organic solvents and, therefore, are more effective in maintaining a liner in a soft condition.

Materials such as rubbers (mercaptan) also have been used as liners. Rubbers, like acrylic resins, are also polymers, but because of their composition they are normally soft, elastic materials at room or mouth temperatures. Acrylic resins must be plasticized to produce a resilient material. Natural rubbers are not favorable because the protein material may be leached out by the oral fluids, and the resultant voids permit fouling of the liner. The silicone rubbers, noted for their water repellency, were the logical choice for a resilient denture liner.

COMPOSITION OF RESILIENT LINERS

Flexene is a powder-liquid resilient liner which is cured at room temperature. The powder is essentially polyethyl methacrylate, a soft polymer, and the liquid is monomeric ethyl methacrylate. The liquid contains a plasticizer, methyl phthalyl ethyl glycolate. As with most materials of this type, the greater the amount of liquid used with a standard amount of powder, the softer is the final product. Since this material cures at room temperature, the liquid contains dimethyl-*p*-toluidine to accelerate the decomposition of the benzoyl peroxide catalyst in the powder.

Soft Oryl has the same general composition as Flexene. The powder is modified polyethyl methacrylate, and the liquid is chemically activated methyl methacrylate containing modifiers. The modifiers may be other monomers or oily plasticizers.

Soft Line powder is an acrylic resin copolymer. The liquid contains a nontoxic plasticizer and nontoxic organic solvents, mainly alcohol.

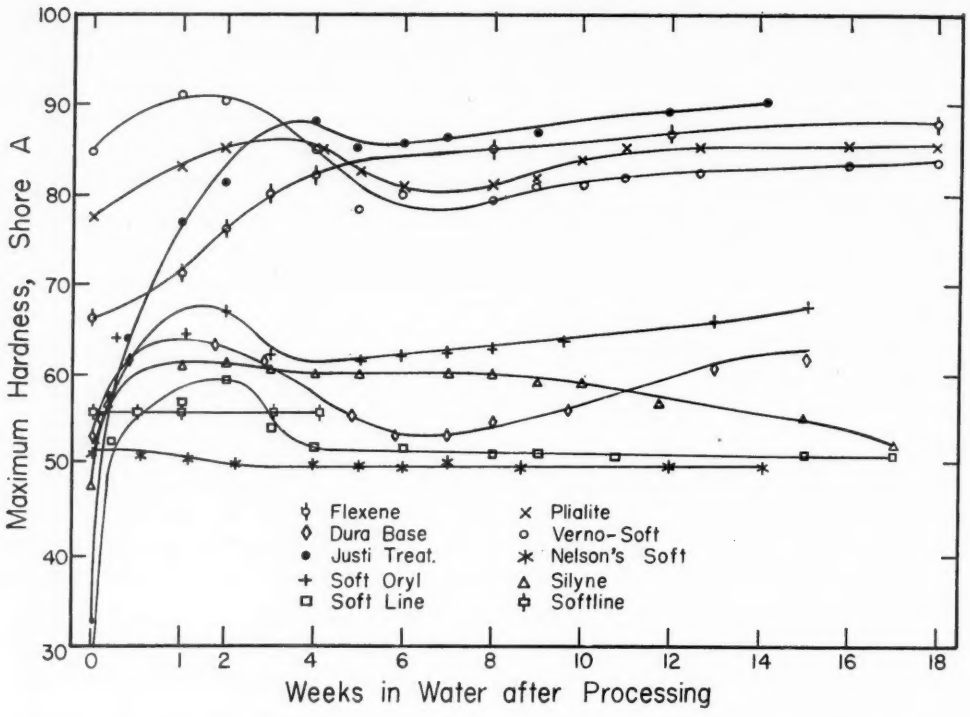

Fig. 1.—Maximum Shore A hardness of resilient denture liners after storage in water at 25° C.

Justi Treatment Reliner is composed of a polyethyl methacrylate powder and an ethyl alcohol liquid. This material sets by a loss of solvent and, therefore, becomes progressively harder as the alcohol plasticizer is leached out of the liner.

Verno-Soft and Plialite are basically soft or flexible acrylic resin copolymer powers and modified monomer liquids which are not chemically accelerated. These materials must be cured at temperatures between 158° and 212° F.

Silyne and Softline are silicone products. A metal organic catalyst is used to convert a low molecular weight paste to a high molecular weight rubber at room temperature.

PROCEDURE

Specimens (48 by 48 by 2 mm.) of the various liners were prepared in a split denture flask using a spring pressure press. Manufacturer's recommendations were followed as to proportions of the various ingredients. As previously stated, the polymer-monomer ratio affects the softness or hardness of the processed specimens.

The materials which cure at room temperature were held under pressure in the split flask with the spring clamp until the material cured. The heat-curing materials were cured 9 hours at 165° F. After curing, the specimens were desiccated as recommended by A.D.A. specification No. 12 for denture base resin, 4.3.2, until constant weight was established. The specimens were weighed, the hardness was

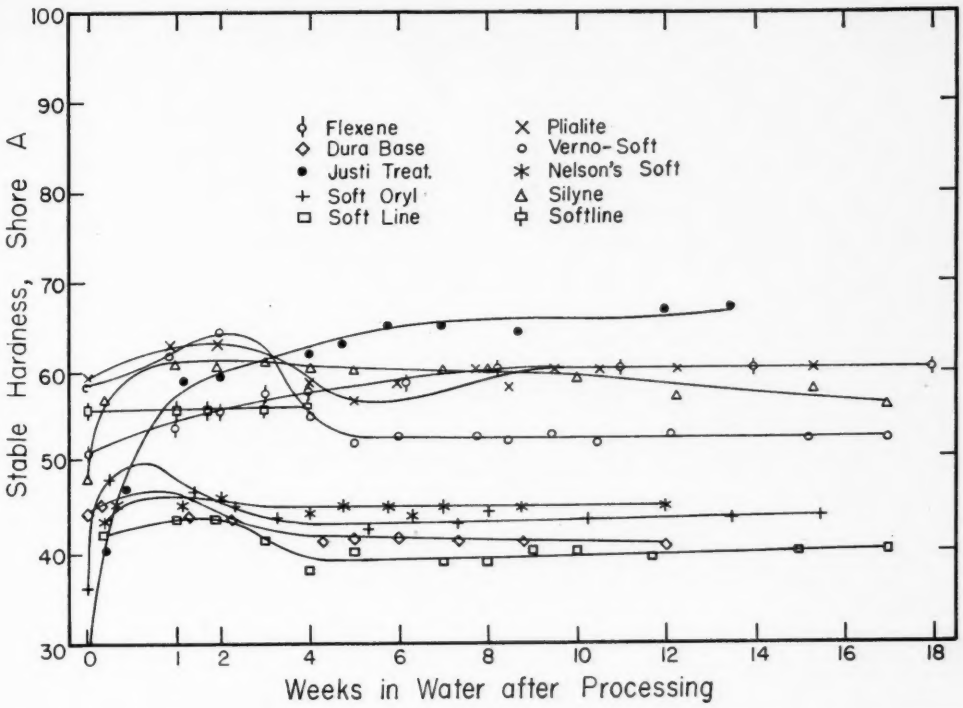

Fig. 2.—Stable Shore A hardness of resilient denture liners after storage in water at 25° C.

determined, and they were stored in distilled water at room temperature. At regular intervals, the specimens were removed from the water, reweighed, and the hardness determined.

TESTING

The specimens were weighed on a chainomatic analytic balance after superficial drying with an absorbent towel. The liner materials were so soft and flexible that hardness tests such as the Rockwell and Knoop did not give satisfactory results. Therefore, another testing method was used.

The Shore A Durometer is used in the rubber industry to determine the relative hardness of elastic materials. This instrument consists of a blunt-pointed indenter 1/32 inch in diameter which tapers to a 1/16-inch cylinder over a distance of 1/16 inch. The indenter is attached to a scale by a lever arrangement and reads from 0 to 100 Shore A hardness units. The more the indenter penetrates the specimen, the lower the hardness value.

The thickness of the specimen and the hardness of the supporting structure affect the observed specimen hardness. Therefore, for purposes of standardization, the 2-mm. thick specimens were placed on a glass slab during testing. Ordinary heat-cured polymethyl methacrylate has a hardness on this scale of 99, while the resilient liners had hardness values from 20 to 91.

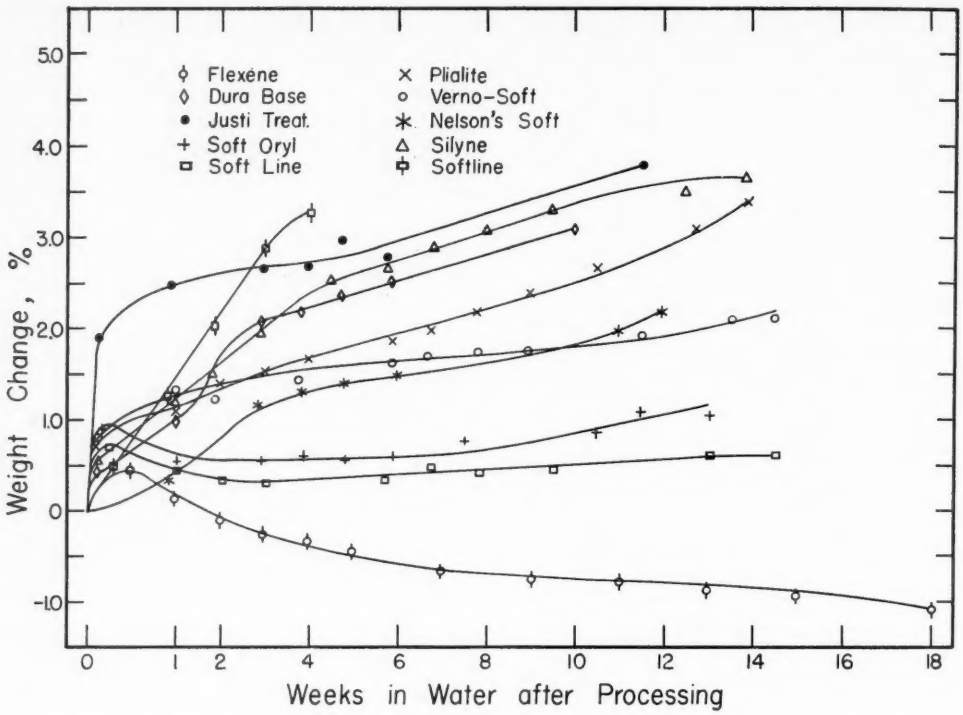

Fig. 3.—Weight changes of resilient denture liners after storage in water at 25° C.

Two types of Shore A hardness values may be obtained. The maximum Shore A hardness reading is obtained by a rapid penetration of the specimen by the indenter. If the load is maintained on the indenter, the soft or flexible materials flow and the hardness reading decreases. After a period of 5 to 15 seconds, a stable hardness value is obtained. This value compared to the maximum hardness value is an indication of the flow of the material.

RESULTS AND DISCUSSION

The original maximum hardness values of the resilient liners, as well as the hardness after storage in distilled water, are shown in graphic form in Fig. 1. The stable Shore A hardness values are presented in Fig. 2, and the weight change is given in Fig. 3. Also, the initial hardness and the hardness after 12 weeks in water are reported in Table I along with the percentage of weight change after 10 weeks in water.

The major portion of the change in hardness in all materials took place within the first 4 weeks. Justi Treatment Reliner showed a large increase in Shore A hardness, from 33 to 88. Soft Line, which was initially too soft to measure, increased to a maximum hardness of 59. These two materials were plasticized by alcohols, and the rapid increase in hardness is due to the loss of alcohol. The difference in final hardness between these materials is a result of the oily plasticizer used in Soft Line

in addition to the alcohol. These two materials are recommended for relining in temporary treatment and, therefore, the change in hardness would be expected. Soft Oryl also is listed as a treatment relining material, but it has an initial hardness of 52 and a maximum value of 77 after 2 weeks. The harder initial value results from the composition of the material.

Flexene had an initial hardness of 66 and gradually increased in hardness to a value of 87 over a period of 18 weeks. This increase appears to result from loss of the plasticizer, as indicated by the gradual loss of weight of the specimens (Fig. 3).

Dura Base, Plialite, and Verno-Soft showed an increase in hardness of 6 to 10 Shore A units over the first 2 weeks, then decreased in hardness between 2 and 6 weeks, and, finally, increased slowly in hardness. This behavior is explained on the basis of an initial loss of plasticizer, followed by sufficient water sorption to decrease the hardness, and, finally, sufficient loss of plasticizer to result in a gradual increase in hardness. This explanation is substantiated by the weight change observations (Fig. 3) which show a marked difference in the rate of weight change at about 2 weeks.

Silyne had an initial hardness of 48, which increased to 60 during the first week. The hardness was stable over the next 9 weeks, after which it decreased slightly. This material is a silicone rubber and, therefore, the initial increase in hardness is probably caused by continued polymerization. The slight decrease in hardness after 10 weeks in water could result from water sorption.

TABLE I. HARDNESS AND WEIGHT CHANGES OF RESILIENT LINERS ON STORAGE IN WATER AT 25° C.

MATERIAL	MAXIMUM HARDNESS SHORE A_1		STABLE HARDNESS SHORE A_2		FLOW SHORE A_1-SHORE A_2		PERCENTAGE WEIGHT CHANGE
	INITIAL	12 WK.	INITIAL	12 WK.	INITIAL	12 WK.	10 WK.
Flexene	66	84	51	60	15	24	−0.8
Dura Base	53	59	44	41	9	18	+3.1
Justi Treatment Reliner	33	89	21	65	12	24	+3.6
Soft Oryl	51	65	36	44	15	21	+0.9
Soft Line	52*	51	42*	40	10	11	+0.5
Plialite	78	85	59	60	19	25	+2.6
Verno-Soft	85	82	58	53	27	29	+1.9
Nelson's Soft Lining	51	50	42	45	9	5	+1.8
Silyne	48	56	48	58	0	0	+3.4
Softline	56	56†	56	56†	0	0	+3.3†

*After 24 hours.
†After 4 weeks.

Softline, which is also a silicone material, and Nelson's Soft Lining, a plasticized vinyl polymer, were characterized by their hardness stability. Essentially, no hardness changes occurred after processing and storage in water.

The resilient liners may be classified into two groups on the basis of their final hardness after storage in water. The first group includes Nelson's Soft Lining, Soft Line, Softline, Dura Base, Silyne, and Soft Oryl. This group of materials has hardness values between 50 and 65 Shore A units. The second group consists of Verno-Soft, Plialite, Flexene, and Justi Treatment Reliner. These materials have hardness values between 84 and 89 Shore A units. Both of these groups, however, are softer materials than heat-cured acrylic resins, which have Shore A hardness values between 98 and 99.

STABLE HARDNESS VALUES

The stable hardness values for any one material (Fig. 2) reflect the same general trend in hardness as the maximum values on storage in water at 25° C. Also, the order of the acrylic resin materials is the same regardless of the measurement. However, the rubber materials, Silyne and Softline, and the plasticized vinyl plastic, Nelson's Soft Lining, are not in the same order. These materials do not show as much difference between the maximum and stable Shore A hardness values as the acrylic resins. This difference is an indication of the flow of the material under the force of the Shore A indenter and is recorded as flow in Table I.

The zero values for the silicone rubber products, Silyne and Softline, and the low values for the plasticized vinyl plastic, Nelson's Soft Lining, point out that after the elastic deformation occurs little plastic deformation or flow takes place. The acrylic resin relining materials had flow values of from 10 or 11 (nearly as low as the vinyl material) to exceptionally high values of 27 to 29 Shore A units for Verno-Soft. In general, it must be concluded that the acrylic resin liner materials flow more than the vinyl or silicone types.

WEIGHT CHANGES

The percentages of weight change for the resilient liners after storage in distilled water are presented in Fig. 3. Also, the percentage of weight changes after 10 weeks' storage in water are listed in Table I. The liners may be classified into three main groups, on the basis of the weight changes observed.

Flexene was characterized by an initial increase in weight of about 0.5 per cent for the first ½ week, then it gradually decreased in weight to −1.6 per cent after 30 weeks in water (not shown on the graph). The initial increase was apparently caused by water sorption, and the decrease after the first ½ week was caused by loss of plasticizer, which overshadowed any further water sorption. After 30 weeks of storage in water, the surface of the specimens was rough and had a blanched appearance. These visual observations substantiate that plasticizer had been leached out of the specimens.

A second group includes Soft Line and Soft Oryl. These materials, like Flexene, had an initial increase in weight between 0.75 and 0.85 per cent after 2 days in water. After 2 days, the weight decreased to 0.3 to 0.5 per cent and then gradually

increased to values of 0.6 to 1.0 per cent. These changes in weight may be explained by, first, water sorption, then loss of plasticizer, and finally, water sorption overshadowing the plasticizer loss.

The third group consists of Nelson's Soft Lining, Verno-Soft, Plialite, Dura Base, Silyne, Justi Treatment Reliner, and Softline. These materials continuously increased in weight with storage time in water. The order of weight increase depended to some extent on the storage time. However, after 10 weeks, the order of increasing amount of weight rise, by product, was: Verno-Soft and Nelson's Soft Lining, Plialite, Dura Base, Silyne, Justi Treatment Reliner, and Softline (based on the high value at 4 weeks).

Generally, a marked decrease in the rate of weight change occurred between 2 and 4 weeks. The large values obtained for the plastic materials were not unexpected on the basis of composition. It was somewhat surprising, however, to find that the silicone rubber liner materials had weight changes of +3.4 per cent or greater. The gain in weight was caused probably by sorption of water by fillers used in the compounding of the materials.

EVALUATION

A number of other physical and clinical properties should be measured in order to properly evaluate a resilient liner. Certain generalizations, however, may be made from the hardness and weight change measurements.

The amount and permanence of resiliency needed depend upon the intended use of the material, for example, whether it is for a temporary or permanent procedure. Two types of liners, Justi Treatment Reliner and Soft Line, have an initially high resiliency, but with time, gradually become harder. The main difference between these materials is their final hardness. The Justi Treatment Reliner has a final hardness in the order of 90, and that of the Soft Line is approximately 50. The remaining liners would be selected on the basis of whether a soft or moderately hard liner would produce the most satisfactory clinical result. The group of soft materials includes Nelson's Soft Lining, Dura Base, Softline, Silyne, and Soft Oryl, and the group of harder liners consists of Verno-Soft, Plialite, and Flexene.

The flow measurements also must be evaluated clinically to determine if this property has clinical significance. If low flow is essential, a silicone rubber liner should be considered. If a large amount of flow is advantageous, the selection of Verno-Soft or Plialite would be suggested.

The weight change values, which are an indication of dimensional stability, show that none of the liners are stable and indicate that dimensional changes would be expected. The most satisfactory materials with respect to weight changes are Soft Line and Soft Oryl.

Certain qualitative observations also are important in the evaluation of resilient liners. None of the materials tested presented any curing problems, although some were of the heat-curing and others were of the self-curing types. The use of liner materials that have composition similar to the denture-base resin is indicated, since they present no problems of adhesion to the denture base. The silicone and vinyl materials, however, present some problems of adhesion to the denture-base materials.

The weight change studies imply that the resilient liners would not be dimensionally stable. Odors, as well as staining, would develop as a result of sorption of oral fluids. Although color stability may not be of prime importance in temporary resilient liner materials, it nevertheless is a consideration from an esthetic standpoint. Patients complain about the burning sensation which occurs during the processing of the self-curing liners when done directly in the mouth. This complaint is found with liners that use acrylic resin monomer liquids, but it has been less prevalent when the liquid is alcohol. This result is observed since the resin monomers are more irritating to the oral tissues than alcohol.

The polishing and finishing characteristics of the resilient liners are of considerable concern. Even the softer plastic materials may be polished and finished by storing in ice-cold water just prior to performing these procedures. This increase in stiffness or decrease in resilience is not sufficient with the silicone materials, and they are best finished with a sharp knife.

SUMMARY

The maximum Shore A hardness of ten resilient relining materials was determined after curing and at intervals after storage in distilled water at 25° C. Products plasticized with alcohol had a rapid increase in hardness, while other acrylic resin polymers or copolymers plasticized with oily liquids showed less rapid changes in hardness when stored in water.

The resilient liners fell into two groups, one having maximum Shore A hardness values between 50 and 65 and the other having values from 84 to 89. The flow of liner materials under a load was indicated by the difference between the maximum and stable Shore A hardness values. The silicone rubber liners had no flow, while most of the acrylic resin liner materials had a moderate amount of flow.

The weight change percentages demonstrated that none of the materials were stable when stored in water at room temperature. The Flexene liner lost weight continuously with storage time after 4 days in water. Soft Line and Soft Oryl were the most stable of the plastic materials; the remainder of the plastic liners and the silicone rubber liners had greater weight increases.

On the basis of the experimental data, a limited evaluation of the resilient liners was presented. Additional studies of physical properties and clinical evaluations of their significance will eventually indicate the materials most desirable to produce specific results.

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THE THEORETIC BASIS OF THE FUNCTIONAL VACUUM METHOD FOR COMPLETE DENTURE CONSTRUCTION

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MANY IMPRESSION METHODS based on limited principles have been used in complete denture construction. The two main principles involved in making impressions are those of the compression and adhesion methods. To understand the "functional vacuum" method, it is necessary to understand the other two methods mentioned.

COMPRESSION METHOD

Modeling compound was introduced to dentistry by the Greene brothers[1] at the beginning of the twentieth century. Thus, placement pressure impressions came into use and were improved by Kantorowicz.[2-4] The compression is based on the creation of a difference between atmospheric pressure inside and outside the denture. Border extensions serve as a seal to maintain a localized vacuum inside the denture around the ridges and hard tissue.[4]

Swenson[5] said, "Many successful dentures are made with the placement pressure type of impression. Apparently, some kinds of tissues are pressed and placed. However, after a long study it is the author's opinion that less soreness and instability is caused by the mucostatic type of impression in the average operator's hand." Sears[6] said, "Atmospheric pressure is a powerful, though transient force which acts to retain the denture bases on their seats." Pryor[7] stated, "Atmospheric pressure manifesting itself in emergency vacuum is most desirable. However, chambers and patented suction cups are not recommended, as nature will tolerate vacuum under a denture only a short time." Other dentists who support the adhesion method have criticized the compression method.[8,9] The principal point of criticism is that the atmospheric pressure that secures retention in the compression method can only have a temporary effect. The lack of permanence is explained by the filling of the vacuum with the mucous membrane of the ridge and hard palate, which gradually lessens the retention. Subsequently, the soft mucosa counteracts the vacuum effect in order to return to its original position. In addition, the excessive material added to the denture for maintaining the vacuum tires the patient psychologically and physically, and the increased weight of the denture decreases the retention (Fig. 1).

ADHESION METHOD

The "mucostatic" impression technique is an application of the principle of adhesion.[10] As its name signifies, the mucostatic impression is a pressureless

impression made with no displacement of soft tissues. The material used for such impressions is zinc oxide and eugenol impression paste, plaster of Paris, or alginate.

Retention is secured in this method through adhesion, cohesion, and atmospheric pressure. Adhesion and cohesion secure resistance against occlusal and vertical pressures, while atmospheric pressure maintains retention against hori-

Fig. 1.

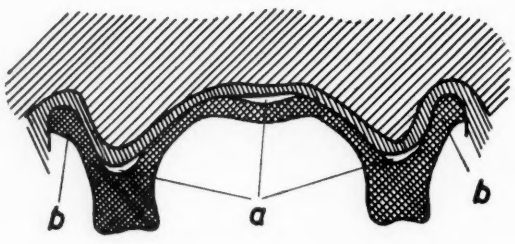

Fig. 2.

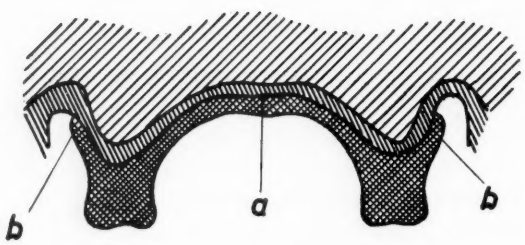

Fig. 3.

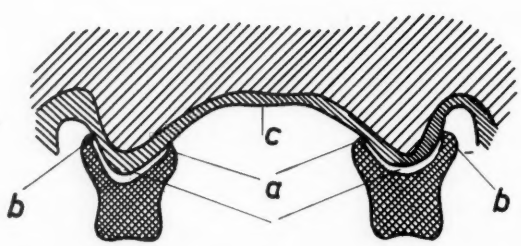

Fig. 1.—A section of the mucosa and a denture made by the compression method: *(a)* the vacuum spaces on the ridges and hard palate; *(b)* the borders serve as a seal in the vestibule.

Fig. 2.—A section of the mucosa and a denture made by the adhesion method: *(a)* the close contact between the denture and the mucosa; *(b)* the borders serve as the seal.

Fig. 3.—A section of the mucosa and a denture made by the functional vacuum method: *(a)* the general vacuum created between the denture and the mucosa; *(b)* the packing ring that serves as the seal; *(c)* the base material does not cover the palate.

zontal pressures. The vacuum caused by horizontal pressure is partial and continues only for a short time.[11] The partial and temporary nature of this vacuum eliminates the causes of traumatic soreness.

Originally, the adhesion method was based only on the adhesive strength; however, this strength was not adequate to maintain retention. Further factors were necessary to increase retention, and so atmospheric pressure was added to

mere adhesion.[12] Kuck[13] has defended cohesion as an additional factor and claimed that the high viscosity of the saliva contributes to cohesion and increases the retention. The successful use of the adhesion method began only after these three factors were combined. There are, however, certain objectionable points in the adhesion method. Pryor[14] emphasizes that this system is not applicable immediately after the extraction of teeth or before the sockets are properly healed.

Some dentists use local vacuum chambers or suction cups to increase retention. This procedure is incorrect. These chambers can be maintained only for a brief period and are eventually filled with mucous membrane; thus they lose their function and become harmful.

As in the compression method, the maintenance of a vacuum for the adhesion method required heavy border extensions of the denture. The overextensions in the vestibules and the soft palate cause justified complaints by the patients (Fig. 2).

FUNCTIONAL VACUUM METHOD

The primary factor of success for a complete denture is retention. Retention is secured largely by adhesion, cohesion, and vacuum. In the functional vacuum method, retention is based neither on cohesion nor on local vacuums, but on a general vacuum created between the entire tissue surface of the denture and the mucosa.

The use of vacuum as a retentive factor in denture construction was suggested in 1883 by the Greene brothers and Ames. This was followed by such abusive practices as the use of vacuum chambers and suction cups which created only temporary retention and caused pathologic changes in the mucosa. The application of atmospheric pressure has been revised by some dentists by the addition of the use of functional borders on the denture.[4,11]

The basic advantages of dentures constructed by the functional vacuum method are (1) greater retention, (2) removal of denture-base material from the palate, and (3) elimination of border extensions, hence, lighter dentures (Fig. 3).

THEORETIC BASIS FOR FUNCTIONAL VACUUM METHOD

The principle of the functional vacuum method is the same as that of a reciprocating pump. Such a pump consists of a cylinder, a piston that can move in the cylinder, and a segment, or packing ring, that stops leakage between the cylinder, the piston, and an admission valve (Fig. 4). The most important part is played by the packing ring.

The cylinder of a reciprocating pump is shown in the form of a hemisphere in Fig. 5. The piston surface is also a hemisphere that fits into the cylinder. For such a device to function as a vacuum pump, a packing ring of the extensible type must be used on the piston, because as the piston moves axially, the distance between the piston surface and the body should remain constant. At the same time, with such a packing ring it is possible to maintain a definite and minimum (enough to prevent adhesion) clearance between the piston and the body. Such a packing

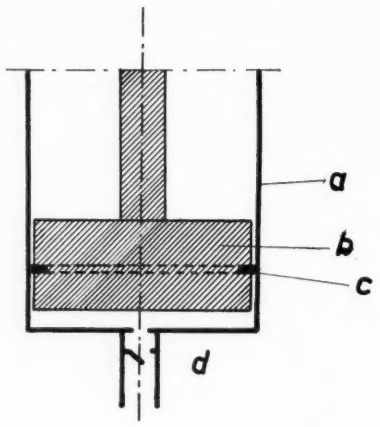

Fig. 4.—A section of the reciprocating pump: *(a)* the cylinder; *(b)* the piston; *(c)* the packing ring belt; *(d)* the valve.

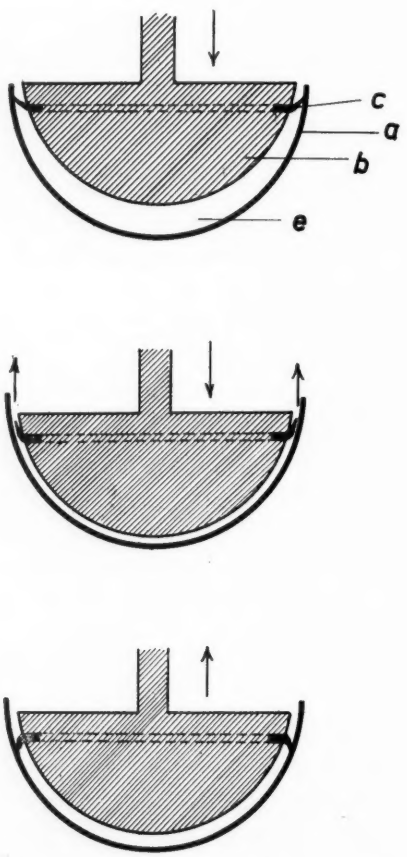

Fig. 5.—The cylinder in the pump section has been replaced with a hemisphere: *(a)* the cylinder; *(b)* the piston; *(c)* the packing ring; *(e)* the vacuum gap between the piston and the cylinder. The three positions indicate the transformation of the pump in function.

ring can always be constructed when the gap between the cylinder and the piston is small. The proper operation of such a system creates a typical vacuum inside the pump.

From the moment the pump starts to operate, increasing resistance is encountered since the outside diameter of the packing ring decreases continuously. If the elasticity or the spring tension of the packing ring is sufficiently large and the packing ring is constructed correctly, although adhesion might exist between the piston and the body at the end of the operation, the piston can rise enough to break the adhesion.

APPLICATION OF THE FUNCTIONAL VACUUM METHOD

Regardless of its form and volume, the denture-bearing tissue plays the same function as the pump piston. Therefore, a denture constructed from a mucostatic impression becomes the cylinder and has a form corresponding to that of the mucostatic piston (Figs. 6 and 7). The packing ring, which has a vital role in this system, is put on the inner borders of the denture as a seal since it is impossible to place it on the mucosa which acts as the piston (Figs. 8 and 9). The lack of resilience of such a seal is counterbalanced by the elasticity of the mucosa (Fig. 10).

FACTORS CONTRIBUTING TO RETENTION

The primary factor for success in denture construction is retention. The factors that contribute to retention in complete denture construction by the functional vacuum method are the (1) vacuum (atmospheric pressure), (2) seal (packing ring), (3) stability (occlusion and leverage), (4) physiologic and anatomic factors, and (5) psychologic factors.

Stability.—Soft tissues and border extensions which take part in ensuring stability in other systems do not play any significant role in the functional vacuum

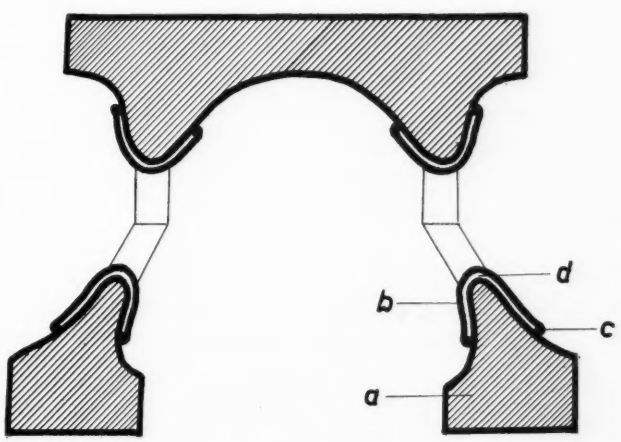

Fig. 6.—The pump system is transferred to the denture: *(a)* the maxillae and mandible (piston); *(b)* the denture (cylinder); *(c)* the packing ring seal; *(d)* the gap between the denture and the mucosa.

method. Stability is obtained by making use of the retention secured from the vacuum created between the denture and the denture-bearing tissue.

Occlusion.—The effects of occlusion on the stability of the denture constructed by the functional vacuum method are the same as in other methods.

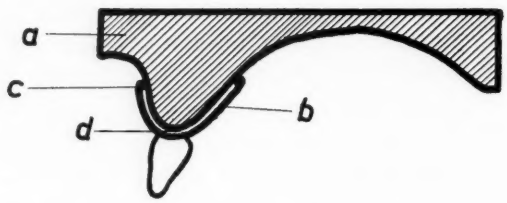

Fig. 7.—A sagittal section of the maxillae: *(a)* the maxillae; *(b)* the denture; *(c)* the packing ring; *(d)* the vacuum gap between the denture and the mucosa.

Leverage.—Leverage plays a harmful role, particularly in the adhesion system, because of the close contact between the mucosa and the denture. Functional pressure applied to the denture at any point may displace the denture by lever action. In the functional vacuum method, however, there is no immediate contact between the denture and the mucosa which might cause leverage. Also, the hard palate is not required for denture purposes, so no lever supports remain.

The hardness of the palatal tissue and the close contact of the denture with this hard tissue sometimes cause breakage of dentures constructed by the adhesion system. The adhesion system provides a relief area for the hard palate to avoid such breakage.[15]

Physiologic and Anatomic Factors.—The retention of dentures constructed by the functional vacuum method is secured through the seal and the vacuum created by this seal. Therefore, to obtain the highest efficiency from the seal, it must be well positioned. This requires a detailed physiologic and anatomic study of the mouth.

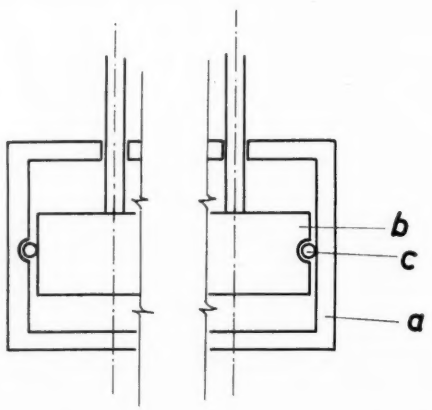

Fig. 8.—The packing ring belt is transferred from the piston to the cylinder: *(a)* the cylinder; *(b)* the piston; *(c)* the packing ring.

The retentiveness of the packing ring seal can be increased with saliva. The viscosity of the saliva directly increases the contact between the mucosa and the packing ring seal and bars the re-entry of air between the denture and the mucosa. Saliva is not vital, however, because no adhesive or cohesive function is required from the saliva in the functional vacuum method. The vital role of the palate in the vacuum method is entirely eliminated. Since this method is based solely on vacuum, there is no need for any tissue contact for adhesion purposes. Therefore, the denture on the palate is removed to the extent permitted by the mouth (Fig. 11). Furthermore, because the borders of dentures constructed by the functional vacuum system do not contact soft mucosa, the adverse effects of this tissue on the retention are eliminated altogether. However, vestibule deformations that prevent the placement of the denture may require surgical adjustments.

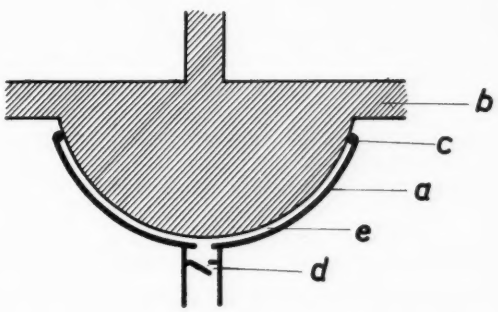

Fig. 9.—A section of the transferred position of the packing ring belt: *(a)* the cylinder; *(b)* the piston; *(c)* the packing ring belt; *(d)* the valve; *(e)* the gap between the cylinder and the piston.

Psychologic Factors.—Dentures constructed with functional vacuum system have important psychologic effects on the patient.

The greatest fear of both the dentist and the patient is a failure in retention. From the moment the denture is inserted it should not move, and steady retention should be maintained. The functional vacuum system amply provides for this requirement. Extreme sensitivity may be encountered in the palate which may cause nausea and sometimes prevents the patient from wearing dentures. This is a continuous source of worry for both the dentist and the patient. Therefore, the removal of the denture base from the palate usually has a favorable effect on the morale of the patient.

The possibility of phonetic handicaps caused by dentures is a further worry for patients. Since dentures constructed with the functional vacuum system are light and do not cover the palate, the size of the oral cavity is not reduced and the movements of the tongue are unimpaired.

OTHER CONSIDERATIONS

Hyperplasia, traumatic soreness, and ulcerations are caused by the movement of the denture, by the contact of denture borders and soft tissues, and by the

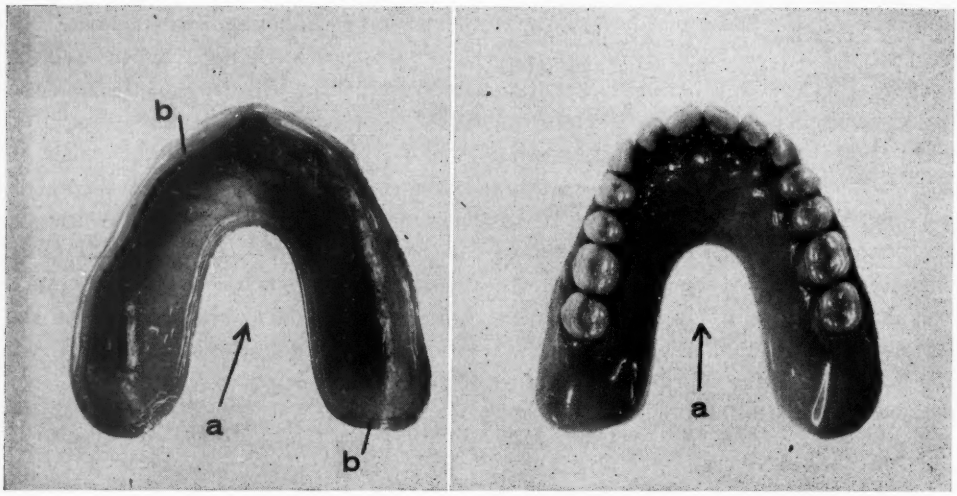

Fig. 10. Fig. 11.

Fig. 10.—The tissue surface of a denture constructed by the functional vacuum method: *(a)* the palatal base material is not present; *(b)* the packing ring belt is placed around the borders.
Fig. 11.—The palatal portion of the denture is not needed in the functional vacuum method.

effects of the relieved edges on the palate.[16] The dentures constructed by the use of the functional vacuum method do not cause pathologic changes. The gap between the mucosa and the denture-base material protects the tissue during slight movement of the denture. Furthermore, since the denture border never extends to the soft movable tissues, traumatic soreness does not occur in these regions. The absence of the palatal portion of the denture eliminates the relief area. Although it could be assumed that the existence of a packing ring seal may cause traumatic soreness, this soreness is prevented by the correct positioning of the seal.

In some instances, complete dentures cause maxillary or mandibular atrophy. Although it can be argued that the existence of the palate in dentures may lessen some of the occlusal pressure on the ridges, such an argument is not fully justified. When a close contact exists between the denture and the mucosa, occlusal pressures may directly affect the ridge before spreading over the palate, thus causing atrophy of the bone. In the functional vacuum method, this objection has been eliminated. The limited amount of air and saliva between the mucosa and the denture serves as a shock absorber and reduces the effects of the pressures that might cause atrophy.

It may be claimed that adhesion eventually occurs between the mucosa and the denture constructed by the functional vacuum method. This is unlikely, because no matter how long the denture has been in the mouth, any small hole in the denture or any damage in the seal causes the denture to fall.

It also may be assumed that the gap between the denture and the mucosa may cause looseness of the denture and irregular movements. This is not true. Movement is prevented by the increasing vacuum created with the slightest movement of the denture and the resistance of the mucosa against functional pressures.

The application of the functional vacuum method has been discussed here in relation to upper dentures. A similar degree of success has been obtained with lower dentures, depending on the condition of the denture-bearing tissues.

SUMMARY

The compression and adhesion methods of making impressions for complete dentures, including their deficiencies and harms, have been discussed. The principles of the functional vacuum method which makes use of atmospheric pressure without benefit of adhesion or cohesion have been explained.

The application of the functional vacuum method permits the elimination of the palatal portion of the denture. Satisfactory results for lower denture construction have also been obtained from the vacuum method.

I am grateful to Prof. Fahir Yenicay and Prof. Tevfik Berkman of the University of Istanbul and to Orhan Boyer, D.D.S., and Habil Amato, M.D., D.D.S., for their assistance in the preparation of this article.

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TROUBLE SHOOTING IN COMPLETE DENTURE PROSTHESIS
Part V. Local and Systemic Involvements*

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PRESENT DIAGNOSTIC TECHNIQUES are insufficient to determine which of the contributing factors oxidation and ventilation is most responsible for sore mouths of denture patients. However, these etiological factors are important both individually and collectively.

OXIDATION

The oral mucosa needs oxidation by direct access of outside air as does the skin, but the border seal of complete dentures blocks off this air. Therefore, it might be reasoned that it would be beneficial to eliminate the border seal entirely. Experience, however, teaches that more sore mouths are observed when the border seal is totally lacking. The conclusion must be that the benefit derived by the mucosa from direct access of air through the denture borders is nullified by factors which the lack of a seal engenders. Retention and stability are greatly impaired with the loss of the seal, and this impairment causes inflammatory conditions in the denture-supporting structures.

VENTILATION

Ventilation exposes the mucosa which supports the dentures to fresh air for oxidation purposes. It also allows accumulated vitiated air to escape, thereby freeing the tissues from noxious gases. To improve oxidation of the mucosa, the patient should rinse the mouth several times a day with a mild antiseptic, oxidizing mouthwash. For better ventilation and "rest" of the tissues, the dentures should be removed from the mouth several times a day. Thus, the blood circulation will be activated and the oxidation and nutrition of the tissues improved. A diseased or disturbed organ or tissue is in need of rest to mobilize all its defensive mechanisms to alleviate the condition

EXCESSIVE RETENTION

Excessive retention is seldom mentioned as a cause of inflammatory conditions of the denture-supporting structures. This condition causes complaints of severe jaw fatigue toward the end of day or necessitates removal of the dentures from the

*Part I, J. PROS. DEN. 9:978-987, 1959; Part II, J. PROS. DEN. 10:42-46, 1960; Part III, J. PROS. DEN. 10:263-269, 1960; Part IV, J. PROS. DEN. 10:490-495, 1960.

mouth. The dentist may find that the retention of one or both dentures is *much in excess* of customary retention. Force may be required to dislodge the denture from its position because of the excessive adhesion.

Excessive retention may be of two types: (1) that which results from extremely favorable adhesion and cohesion and (2) that caused by extreme intimacy of contact between the denture and the mucosa. Such intimacy is not of a physiologic nature, but is of pathologic origin. This condition is found usually in people who are in a state of tension and grind and gnash their teeth to excess. The dentures may be of high quality with balanced occlusion.

Bruxism drives complete dentures in good balanced occlusion into excessive intimacy of contact with the underlying mucosa. This leads to a chronic inflammatory condition of the oral mucosa because the excessive pressure interferes with the blood circulation. The patient may not experience any particular pain, but is beset, instead, with a heavy, numb, and tired feeling throughout the entire extent of the dentures.

This symptomatology should not be confused with that arising from traumatic occlusion. In traumatic occlusion, the patient's complaint of a heavy and tired feeling is limited usually to one side and there is some slight pain. Also, a differential diagnosis must be established between excessive retention and *good* retention that accompanies a correct border seal. With correct retention, the dull, heavy, and tired feeling subsides within the first 2 weeks after the insertion of the dentures.

INADEQUATE RETENTION

The chief problem in sore mouth conditions arises from inadequate retention. Inadequate retention causes damage to the mucosa in two ways: (1) the movement of the denture injures various sections of the supporting and adjacent structures and (2) the patient acquires the habit of reseating the dentures with the fingers and tongue. In either instance, the physiologic endurance of the mucosa is overtaxed and pathologic readaptation of the tissues follows. In addition, loose dentures have a disturbing effect upon the patient's psyche which leads to the formation of tenacious and stubborn habits.

The lingual surface of the mandibular ridge is the most important target of the loose lower denture. Irritations appear in various sections, particularly on the sharp mylohyoid line. These irritations can hardly be seen, because the loose denture does not hit the same spot repeatedly enough to form a clear-cut ulceration. However, the experienced eye will discern small grayish white irritations in the desquamation of the superficial layers of epithelium. If the spot is painful to palpation and some slight morphologic change is suspected, the denture may be reduced slightly and polished. However, this is a palliative treatment. The only way to cure this condition is to correct the inadequate retention.

The inadequate retention is caused usually by denture border overextension, denture border underextension, or both. A slightly overextended denture is to be preferred to a slightly underextended one, but correct extension should always be the goal (Fig. 1). An adequate occlusion develops intimacy of contact between the denture and its supporting structures, thereby greatly improving denture retention.

SYSTEMIC DISEASES

Dentists must be familiar with local manifestations of a general origin. A patient whose resistance has been lowered by a general ailment experiences two types of difficulties: (1) the oral tissues are more vulnerable to trauma and infection and (2) their healing qualities are lowered considerably. The severely diabetic person develops sores on the denture-supporting structures, whereas a healthy person under similar circumstances does not. Furthermore, the sores of the diabetic patient will respond poorly to treatment as long as the blood sugar level remains high. With its descent to a normal level, there is improved response

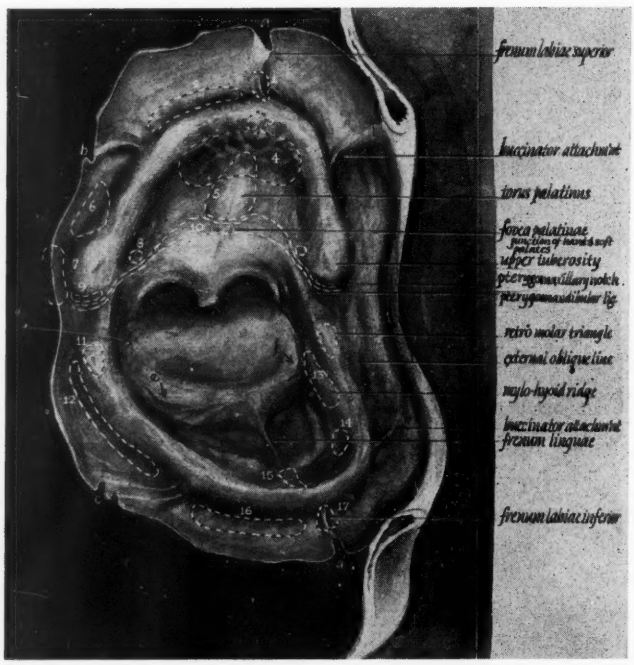

Fig. 1.—The anatomic landmarks from a stone cast are superimposed upon the oral structures. The arrows show slitlike ulcerations in the lining mucosa on the undersurface of the tongue. In this area, the lining mucosa is not keratinized and is highly sensitive to irritation.

to treatment. A similar relationship exists with other general diseases, such as tuberculosis, syphilis, and blood dyscrasias. The inflammatory condition is not due so much to the severity of the trauma as to the low resistance of the tissues.

Dental offices should be equipped to perform basic biologic tests for anemia, determination of the blood sugar level, sugar and albumin in the urine, etc. This does not imply that the dentist is assuming the role of the physician, but the dentist is frequently in an excellent position to note the presence of general disease from the behavior and reactions of the oral tissues. I have seen numerous complete dentures in which the occlusion and denture borders were mutilated by over-

Fig. 2.—The features of border extension for stability and retention that are inherent in this impression should be retained permanently in the completed denture. (From Swenson, M.: Complete Dentures, St. Louis, 1940, The C. V. Mosby Company.)

enthusiastic adjustments (Figs. 2 and 3). These dentures were given up as failures by the dentists, only to have them learn that the real cause for the failure was a general physical or emotional disturbance.

Lichen planus may become the chief cause for failure of complete dentures. Patients afflicted by this condition are usually emotionally hypersensitive and frequently suffer from cancerophobia. They fear that the lichen planus patches rubbing against the buccal surfaces of the posterior teeth and the denture-base material may lead to cancer. Dentures are mutilated by setting the teeth so far away from the cheeks that the tongue becomes completely imprisoned. The lower denture base is rendered useless by gradually reducing it until it becomes flagrantly underextended. If a proper diagnosis had been established originally, with proper psychologic preparation of the patient, mutilation of the dentures would not have occurred.

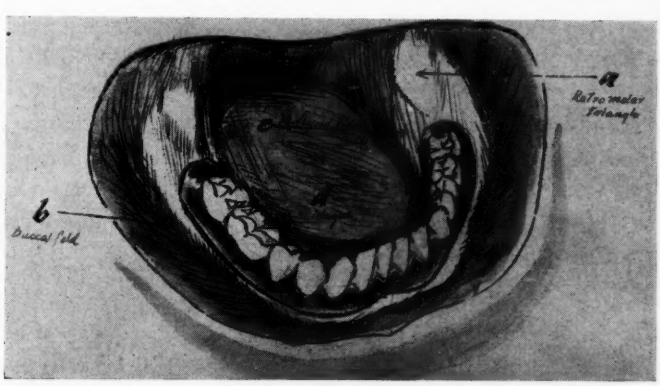

Fig. 3.—Incorrect adjustments result in an excessively underextended lower denture with complete mutilation of the denture borders.

The dentist should be extremely alert in the diagnosis of lichen planus (and its concomitant skin lesions) and what resembles it, but is a much more serious condition, leukoplakia. The latter may be a *precancerous lesion* and should always be kept under strict supervision by both the dentist and physician. Leukoplakia on the palatal vault and alveolar ridges often disappears when covered and well protected by dentures. The tissue surface of the denture over leukoplakia must be relieved properly and polished smoothly. In addition, the dentures must be stable and the occlusion well balanced. Ideal cleanliness of the dentures is imperative and the dentures must be inspected frequently.

All diseases that tend to lower the vitality of the individual lower the resistance of the oral mucosa. The oral cavity, one of the organs of the human body, suffers whenever the entire organism is affected. The degree depends upon the type and severity of the systemic disease.

ENDOCRINE AND EMOTIONAL DISTURBANCES

The ill effects of endocrine dysfunctions and emotional disturbances upon the mucosa are extremely difficult to differentiate. There is such intimate interplay and reciprocity between these two factors that it is best to treat them together.

A great number of women in menopause or, more so, in the postmenopausal state present a definite problem to the prosthodontist. They complain at frequent intervals of vague, diffuse pain of the denture-supporting structures. On examination, no specific irritation or ulceration is found. Instead, the entire mucosa under the dentures manifests a red, glossy appearance and is slightly edematous. The sensitivity of these tissues to finger pressure or mere contact and the observed morphologic deviation suggest that two main factors may be at work simultaneously: (1) traumatic occlusion and (2) poor cornification of the mucosa because of a deficiency of estrogenic hormones. A similar picture, on rare occasions, may be observed in men. They manifest nervous and emotional tension very characteristic of women in the stage of menopause. Cancerophobia is an outstanding affliction. The condition of the mucosa resembles that classified by some periodontists as desquamative gingivitis.

The oral or topical administration of estrogenic hormones by an endocrinologist has been found by some investigators[1] to be useful. Our patients who have benefited have been treated by simultaneous perfection of the occlusion, administration of estrogenic hormones, improvement in diet and nutrition, vitamin administration, and reassurance. We do not know to what extent the condition has been benefited by any one of these therapeutic agents. However, we do know that endocrine dysfunctions themselves are decreased by proper nutrition, a balanced diet, and an adequate intake of vitamins.

SUMMARY

The diagnosis and treatment of inflammatory conditions in the oral cavity cannot be limited to one area alone. The boundaries must be extended to include a complete history of the patient's life with its ramifications into every department

of human endeavor. Certain oral conditions are due to the patient's occupation. Others are a local manifestation of a general condition, such as poor nutrition and endocrine dysfunctions. Systemic therapy in these instances is conducive to best results, whereas topical treatment fails.

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ELECTROMYOGRAPHIC ANALYSIS OF JAW MOVEMENTS

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PREVIOUS ARTICLES have reported the frequency response requirements encountered in dental electromyography and have outlined a practical means of obtaining electromyograms of jaw muscle activity under optimal conditions. The influence and inadequacy of a single electrode reference on electromyograms was demonstrated and the necessity for using the multielectrode or standard generalized reference was established.[1,2]

The impetus of electromyography has reached beyond the determination of simple muscle function or dysfunction into the areas of orthodontics, periodontics, prosthodontics, and oral surgery. The electromyographer must be cognizant of the limitations of his instrumentation, and the dental profession likewise must realize the limit of its usefulness.

The objectives of this study were (1) to determine the range of variability of muscular activity in jaw movements for a group of patients, (2) to determine the range of variability in a series of electromyograms of one patient, (3) to provide electromyographic data obtained with high-fidelity techniques for future reference, and (4) to provide an analysis of the role played by the external pterygoid muscles in trained (learned) jaw movements.

In order to accomplish these objectives, statistical techniques were employed to analyze data derived from the electromyograms.

METHODS

All electromyograms were made with an ink-writing Grass model III-D electroencephalograph operating on electromyograph settings. The amplifiers were operated at sensitivity settings recommended for EMG tracings, so that an input signal of 50 μV produced a pen deflection of 6 mm. Muscle filters were off. A paper speed of 3 cm. per second was used. A five-point† generalized reference network was used.

Surface electrodes described previously[3] were used to record from all muscles except the external pterygoid muscle. Recordings from this muscle were obtained

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**Associate Professor, Division of Biophysics, Department of Physiology.
***Electroencephalograph Specialist, Columbus Receiving Hospital and State Institute of Psychiatry.
†Both ear lobes, nose, occipital point, and vertex.

using a curved suture needle insulated with an acrylic resin spray except for 1.5 mm. at the tip. This needle electrode was injected intraorally near the insertion of the lower head of the left external pterygoid muscle to the condyle.

The surface electrodes were attached to the anterior, middle, and posterior portions of the left temporal muscle, the posterior portion of the right temporal, the left masseter, and the right and left digastric muscles. The electrode on the masseter muscle was placed low and near the posterior border to minimize the spread of electrical potentials from the buccinator and external pterygoid muscles.

Interelectrode resistance was measured with a standard ohmmeter. Both types of electrodes were adjusted when necessary to produce interelectrode resistance of less than 10,000 ohms prior to making any recordings.

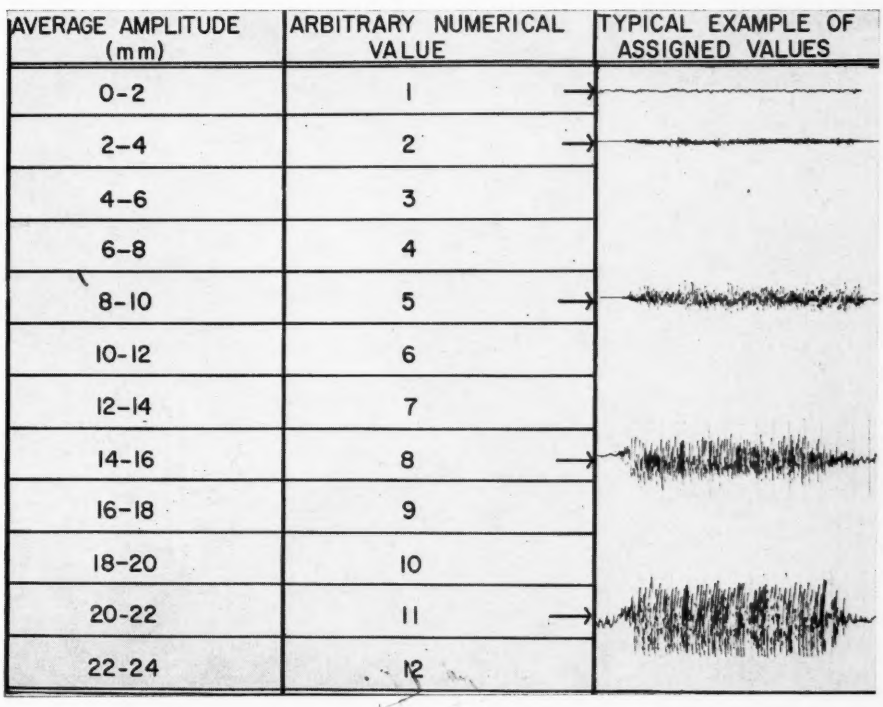

Fig. 1.—Arbitrary values were assigned according to the height of the electromyographic tracing to facilitate the measurements of the records.

The 10 dentulous subjects used for the experiment were a select group of dentists and dental students who were familiar with the trained jaw movements used. All of the jaw excursions were explained to the subjects and practiced prior to making the recordings. Twenty-three learned mandibular excursions were executed and sustained for 2 or 3 seconds and then repeated at least five times by each person.

Thus, 115 recordings were obtained from each of 10 subjects, making a total of 1,150 recordings, fifty for each jaw position. Fifteen of these basic movements

TABLE I. STATISTICAL ANALYSIS OF THE MUSCLES STUDIED

JAW MOVEMENT	MEAN								STANDARD DEVIATION								STANDARD DEVIATION OF THE MEASUREMENT ERROR							
	MUSCLES*								MUSCLES								MUSCLES							
	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
Right lateral excursion	1.40	1.62	2.67	2.47	7.72	3.64	5.04	6.03	0.44	0.49	0.56	1.07	2.48	2.88	3.86	3.17	0.26	0.39	0.70	0.56	1.52	1.26	2.06	1.30
Left lateral excursion	2.04	3.40	5.44	2.13	1.76	3.33	3.67	2.80	0.54	1.82	2.32	0.79	0.60	1.21	1.43	0.75	0.54	1.01	1.36	1.07	0.52	1.22	1.37	0.51
Clench	9.58	9.68	8.08	5.68	4.63	4.40	4.02	8.83	2.20	1.71	2.75	2.41	1.74	2.08	1.17	2.67	1.49	1.62	1.50	1.18	1.08	1.06	1.12	1.33
Retrude	2.96	4.60	5.51	2.98	2.58	6.11	6.80	6.80	1.50	2.74	2.96	2.04	1.29	3.66	4.04	3.50	1.66	2.07	1.88	1.19	1.02	1.66	1.64	1.08
Protrude	1.58	1.62	2.91	3.27	7.00	4.96	5.76	2.80	0.65	0.49	0.55	2.29	1.99	2.67	3.54	0.99	0.42	0.26	0.88	1.62	0.98	2.43	2.45	0.43
Open uncontrolled	1.52	1.75	3.35	2.42	5.77	8.10	8.30	2.77	0.71	0.70	1.85	0.89	1.89	3.52	3.68	1.12	0.46	0.46	1.17	0.84	1.62	1.26	0.88	0.46
Open hinge	2.62	4.80	5.75	2.05	1.88	5.80	6.50	6.43	1.21	2.29	3.16	0.53	0.77	3.06	3.56	2.61	1.28	1.58	1.59	0.73	0.79	1.52	1.35	1.59
Clench right	3.89	3.51	3.76	4.87	4.98	3.87	4.76	7.88	2.53	2.97	3.14	2.40	2.93	2.20	3.12	2.38	0.73	0.80	0.65	0.94	0.54	1.04	1.53	1.84
Clench left	7.27	8.73	8.31	2.96	2.51	2.84	2.96	2.45	3.59	2.86	2.84	1.40	1.09	2.10	1.90	0.95	1.26	1.44	1.50	1.05	0.51	1.48	1.39	0.80
Clench protruded	3.78	2.84	2.78	4.82	5.60	3.91	4.42	2.28	2.54	1.50	0.54	1.96	1.74	2.06	2.71	0.56	0.92	0.71	0.60	0.97	0.99	1.38	1.20	0.70
Protruded right	1.60	1.68	2.72	2.92	7.50	4.08	5.45	3.77	0.66	0.65	0.86	2.28	3.08	2.74	3.70	1.78	0.40	0.39	0.51	0.80	0.67	0.94	1.41	1.36
Protruded left	2.51	3.60	4.96	4.22	2.84	5.49	6.29	3.22	0.62	1.78	2.31	1.36	3.52	2.72	3.29	1.30	0.88	1.10	1.46	0.64	1.17	1.08	1.44	0.81
Slide right	1.20	1.31	2.08	1.71	4.14	2.51	2.26	3.68	0.31	0.41	0.58	0.46	0.81	2.80	2.30	2.50	0.51	0.27	0.45	0.45	0.56	0.36	0.61	1.21
Slide left	3.70	5.65	5.82	1.52	1.80	2.10	2.15	1.72	3.26	3.15	3.25	0.42	0.69	1.99	1.92	0.36	0.59	1.05	1.40	0.33	0.40	0.79	0.58	0.30
Slide forward	1.52	1.42	2.15	1.72	4.38	2.32	2.22	1.68	1.02	0.46	0.77	0.56	1.48	1.86	1.54	0.43	0.38	0.41	0.52	0.48	0.69	1.00	0.51	0.34

*(A) Left anterior temporal muscle, (B) left mid-temporal muscle, (C) left posterior temporal muscle, (D) left masseter muscle, (E) left external pterygoid muscle, (F) left digastric muscle, (G) right digastric muscle, (H) right posterior temporal muscle.

(listed in Table I) are reported at this time. Practicality, spread of isopotential electrical fields, time, and need for additional study were factors limiting the work on the eight movements not reported.

Because of the differences (variability) on electromyograms for the same movement in different persons, and the variability within the same person, some standardized means for interpreting the varying amounts of recorded electrical activity was sought. Gross visual measurements are fraught with much error. Any such method other than use of electronic integrators would be open to criticism and not altogether free from inherent errors. In lieu of integrators, it became necessary to devise some relatively simple, more valid means of measuring the amounts of electrical activity recorded. Therefore, arbitrary values from 0 to 12 were assigned according to the height of individual spikes (2 to 24 mm.) as measured with a transparent millimeter ruler (Fig. 1).

In instances of increased or decreased frequency, or where the spikes were in the fringe area of being either too long or too short for the arbitrary group, values were classified into the next appropriate group. All measurements were made by two of the authors (J.B.W. and J.C.H.) and some were double checked to minimize or correct differences in tabulation.

Variation betwen the measurements arises from two factors: (1) the difference between subjects and (2) the measurement error. The difference between subjects is described in terms of the population standard deviation which is interpreted as follows: If the muscle activity were known accurately on every individual in the population, 68 per cent of that population would fall in the range determined by the population average plus or minus the population standard deviation. Virtually all of the population would have muscle activity between the population average plus or minus three times the population standard deviation.

The standard deviation of the measurement error may be interpreted as follows: Suppose that one subject from our population had been measured under identical circumstances many times; then 68 per cent of the measurements made on this person would fall between his average muscle activity plus or minus the standard deviation of the measurement error. A similar statement could be made for each subject. The value of the average muscle activity changes from person to person but the standard deviation of the measurement error does not. The population standard deviation measures the changes in average muscle activity in the population. The estimates of the population mean, the population standard deviation, and the standard deviation of the measurement error for all muscles and movements tested are shown in Table I.*

RESULTS

Only gross differences in muscular activity will be elaborated because of the large number of possible comparisons that can be made from the available data (Table I). Any comparisons made are limited in significance by the accuracy of

*Data analysis conducted by the Department of Statistical Analysis, Ohio State University.

the methods employed obtaining the data, the variabilities in a human test population, and the capabilities of the instrumentation. The variabilities between the different subjects is evidenced in column 2 and within the same subject in column 3 of Table I. The mean value and the standard deviation of the mean are shown for all movements in Figs. 2 and 3. The illustrated standard deviation indicates the expected range of spread of values for 68 per cent of all the measured electromyograms for any one muscle on a particular movement.

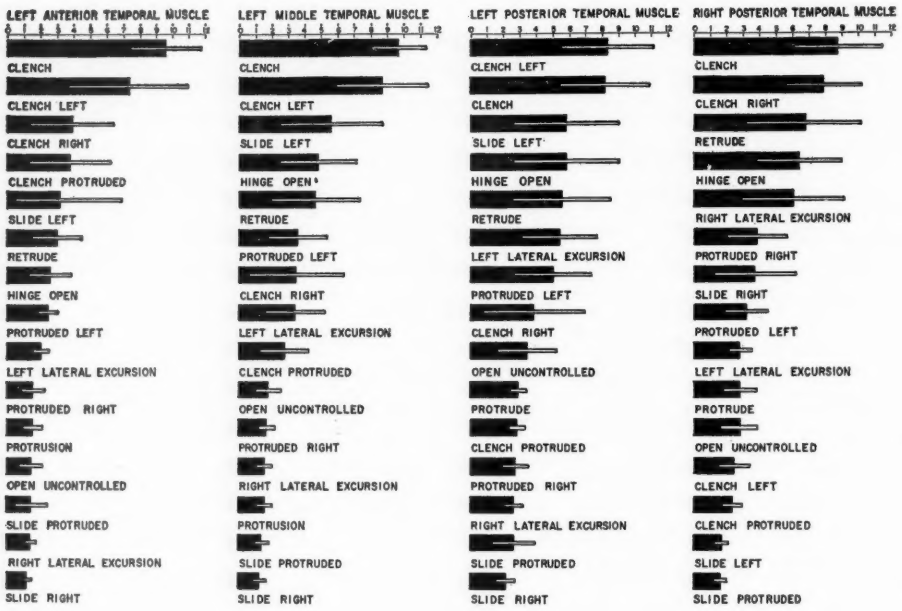

Fig. 2.—The mean values for the muscles are listed in descending order for the various jaw movements tested. The light bars indicate the standard deviation of the mean.

Temporal Muscle.—The greatest amount of electrical response was recorded from the three parts of this muscle during a normal clench and for a clench on the ipsilateral side (Fig. 2). Moderate activity was noted from the middle and the posterior parts of this muscle during both retrusions and hinge openings of the mandible and during lateral or protruded lateral excursions toward the ipsilateral side. The anterior part of the muscle was somewhat less active for these movements. Practically no activity above the resting tonus was noticed during forward protrusion, uncontrolled openings, or any of the other trained excursions of the mandible. Similarity was observed between the right and left posterior parts and between the middle and posterior parts during comparable mandibular excursions (Fig. 1).

Masseter Muscle.—The mean electrical response from the masseter muscle was somewhat smaller than that recorded from the other muscles tested (Figs. 2 and 3). All subjects were cautioned against powerful clenches in order to keep all

responses proportional and still within the limitations of the instrument. The various movements were executed without facial contortions to prevent the spread of buccinator muscle activity to the masseter electrode. Maximum recorded electrical activity from the left masseter muscle was recorded during a clench. Moderate activity was observed during protruded clenches and clenches on the contralateral sides. Lesser activity was recorded during ipsilateral clenches. The masseter muscle was significantly inactive for all subjects during the other jaw movements.

Left External Pterygoid Muscle.—The highest recorded electrical response was observed during contralateral excursions, protruded right movements, and forward protrusions of the mandible (Fig. 3). Moderate electrical response was recorded during uncontrolled openings, protruded clenches, and contralateral clenches. Little activity was recorded during ipsilateral excursions, hinge openings, or retrusions of the mandible. The standard deviation of the mean was significantly small, particularly in instances of external pterygoid muscle inactivity.

Right and Left Digastric Muscles.—Considerable similarity in the tabulated values was seen for the right and left digastric muscles (Fig. 3). The highest recorded activity for both muscles was obtained during, in descending order, uncontrolled openings, retrusions, hinge openings, protruded left movements, and

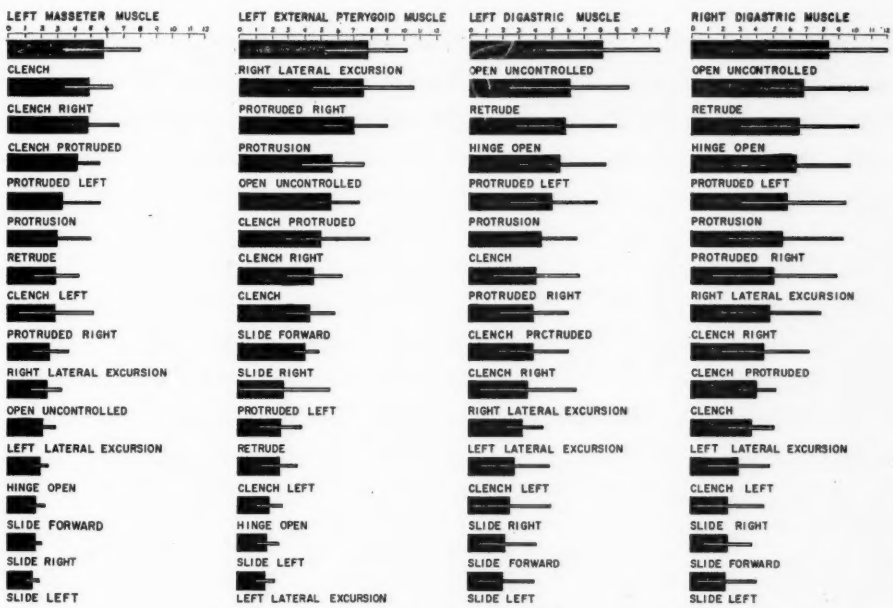

Fig. 3.—The mean values for the muscles are listed in descending order for the jaw movements tested. The light bars indicate the standard deviation of the mean.

forward protrusions. The least amount of activity was seen in the same descending order for both the right and left digastric muscles as follows: left lateral excursion, clench left, slide right, slide protruded, and slide left. The right digastric muscle usually produced more electrical response than did the left digastric muscle.

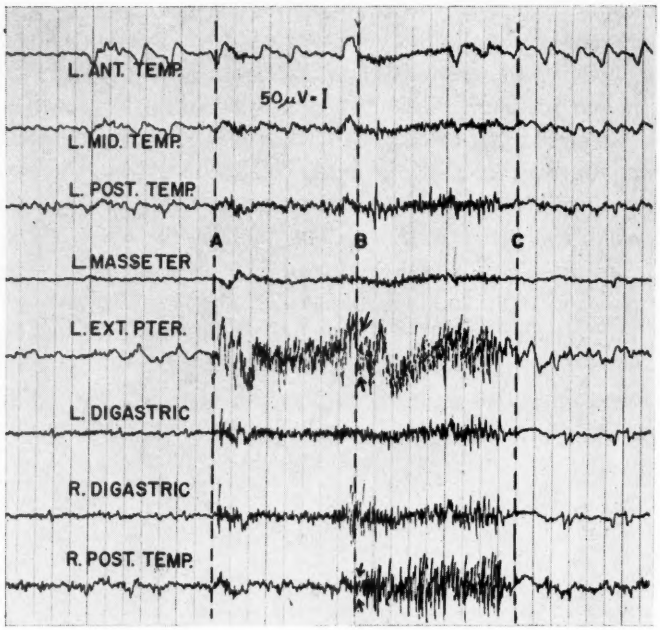

Fig. 4.—An electromyogram made during a protruded right lateral excursion of the mandible: *(A)* the beginning of the forward protrusion which is maintained to *B; (B)* the beginning of the protruded right lateral movement which is maintained to *C*. Arrows show the continued activity of the left external pterygoid muscle and the increased activity of the posterior fibers of the right temporal muscle as the jaw was moved to the protruded right position, *B* to *C*.

DISCUSSION

A proportional increase in electrical activity is seen in conjunction with an increase in muscular response. However, such muscular response does not indicate whether the active muscle is contracting isotonically to move a part or isometrically to fix or stabilize that part. The type of contraction must be determined by other means.

The data indicate that the temporal muscle initiates closures of the mandible and produces the initial power on a clench. The middle and posterior portions of this muscle appear to be capable of voluntary unilateral contraction as evidenced in right and left lateral excursions and protruded right and left excursions. The posterior portions of the temporal muscles contracting on each side simultaneously produce or assist the digastric muscles in retrusion of the mandible. The retruded fixation of the condyles is maintained by these same muscles during hinge openings.

During the ipsilateral clench, the jaw is positioned primarily by the external pterygoid muscle as the teeth are forced together by the closing muscles. The jaw is stabilized by the intercuspation of the occluding cusps on the working side, by the cusp contacts (if present), and by the external pterygoid muscle on the balancing side.

Contrary to some reported findings,[4-7] both the temporal and masseter muscles were significantly inactive in forward protrusions and uncontrolled openings of the

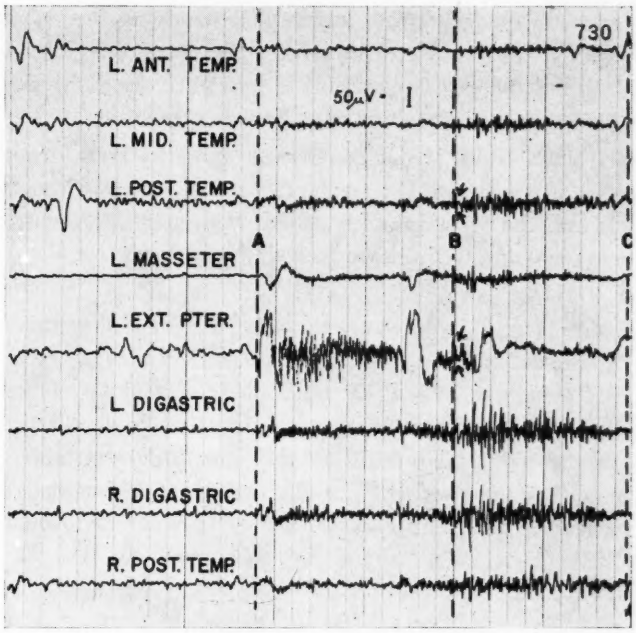

Fig. 5.—An electromyogram made during a protruded left lateral excursion of the mandible: *(A)* the beginning of the forward protrusion which is maintained to *B; (B)* the beginning of the protruded left lateral movement which is maintained to *C*. Arrows show the decreased activity of the left external pterygoid muscle and the increased activity of the posterior fibers of the left temporal muscle as the jaw was moved to the protruded left position, *B* to *C*.

mandible. This lack of antagonistic response from these muscles can be explained by (1) the reliable multielectrode reference network used, careful electrode placement, and subject selection, (2) anatomic structures (ligaments, bone, and soft tissue, by their positional relationship to the mandible, limit or prevent overopening or subluxation of the condyles), (3) elimination of buccinator muscle activity by electrode positioning and by careful observation and instruction of the subjects, and (4) not recording overlapping electrical potentials from the external pterygoid muscles which are active during these movements. Two investigators[8,9] have reported that the temporal muscle does not function during protraction and the latter points out that any activity recorded from the temporal electrode during protraction is erroneous because of the location of the reference electrode.[9]

Considering the intended limitation of power during clenches and the anatomic structure, position, and powerful design of the masseter muscle, it is not surprising that this muscle did not produce greater electrical activity during clenches.

The data show that the masseter muscle does not direct the mandible into eccentric positions. Certainly this muscle could overcome directive contractions of the guiding mandibular muscles resulting in a mandibular position of centric occlusion probably in very close proximity to centric relation. Pain, ligaments, the components of the temporomandibular joint, and cusps (when teeth are present) would limit or prevent a powerful closure into any eccentric position. The increased

activity of the masseter muscle during a clench on the opposite side can be explained by the stretch reflex. The masseter and internal pterygoid muscles form a sling for the mandible. Thus, when the mandible is moved to the right side, the left masseter muscle is stretched and its contraction becomes more forceful (Fig. 3).

Needle electrode activity is not comparable quantitatively to surface electrode activity. Therefore, it is impossible to make direct comparisons between the external pterygoid muscle and the other muscles tested. However, the recorded values from the external pterygoid muscle indicate its relative activity for the different movements analyzed.

The external pterygoid muscles are the sole movers of the mandible during any protrusive or lateral excursions. They combine with the digastric muscles to produce uncontrolled openings. When the mandible is moved to one side from a protruded position, the external pterygoid muscle on that side relaxes while the posterior portion of the temporal muscle on the same side contracts to produce the backward movement of the condyle. The external pterygoid muscle on the opposite side remains contracted to fix its condyle in the forward position (Figs. 4 and 5). This supports Sicher's statements concerning this movement.[10]

The external pterygoid muscles, contracting individually, move the mandible laterally in sliding excursions. These movements are guided by the cusps, with the condyle on the same side fixed by the middle and posterior parts of the temporal muscle. Forward sliding results from contraction of both external pterygoid muscles, with the guidance and stabilization of the mandible coming from the anterior teeth, the positions of the condyles in the fossae, and the posterior balancing tooth contacts when present. The activity recorded from all muscles is greatly reduced in jaw movements when the teeth contact, because the teeth both guide and stabilize the mandible.

No increase in activity was observed from the left external pterygoid muscle during left lateral excursion of the mandible, which indicates that the external pterygoid muscle does not fix the condyle on the working side. Therefore, the direct lateral slide of the mandible (Bennett movement) is not opposed by this muscle. The lack of activity from the external pterygoid muscle during retrusions of the mandible indicates that this muscle does not prevent posterior displacement of the condyles. Such displacement is prevented by the attached ligaments and by the shape of the mandibular fossa. The lack of activity from the external pterygoid muscles during hinge opening confirms the previous work that the hinge movement is possible from a neuromuscular standpoint.[3]

The right and left digastric muscles function together in the jaw movements tested. They show greatest activity as movers of the mandible and moderate activity when guiding or stabilizing a movement. The digastric muscles are movers of the mandible in all types of retrusive and opening movements. The studies failed to show any definite pattern of synergistic or antagonistic relationship between the digastric and external pterygoid muscles.

The activity from the digastric and the posterior part of the temporal muscles indicates that these muscles, at least to some degree, could oppose subluxation of the

condyles. However, subluxation is prevented primarily by the articular eminence and the mandibular ligaments.

It is interesting that in all excursions the right digastric muscle showed slightly more activity than the left digastric muscle. Suggested explanations are (1) the fact that all subjects were right handed, (2) a possible pain factor from the needle electrode in the left external pterygoid muscle, or (3) overlapping fields of electrical activity from the suprahyoid muscles and the muscles of the tongue.

SUMMARY AND CONCLUSIONS

Electromyograms were made on 10 subjects for fifteen different jaw movements. Each movement was repeated five times per person, giving a total of 750 records. The recordings were subjected to statistical analysis to determine the mean, the standard deviation, and the standard deviation of the measurement error. The results were discussed as related to the function of the muscles during the movements tested. The important findings were:

1. The temporal muscle is capable of unilateral and fractional response but does not show increased activity in any part during protrusions or uncontrolled openings.
2. The right and left digastric muscles did not function individually. Their greatest activity was during uncontrolled openings and retrusions of the mandible.
3. The masseter muscle had the greatest activity during clenches into centric occlusion, with little or no indication of increased response during protrusion or uncontrolled openings or in lateral directive jaw positions.
4. The external pterygoid muscle was very active during contralateral excursions, uncontrolled openings, and protrusions but was inactive during hinge openings of approximately 1 cm.

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REMOVABLE PARTIAL DENTURES

MOUTH PREPARATION FOR REMOVABLE PARTIAL DENTURES

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THE PROBLEMS OF THE DENTIST in making a removable partial denture are similar to the problems of the architect in designing a building. The architect must interpret the effect conditions at the building site will have on the building. He searches for defects that need correction to assure success. The dentist likewise directs his attention toward detecting, correcting, and eliminating imperfections.

Mouth preparation is directed toward the reduction of stress in order to protect and preserve teeth and tissues. To evaluate the risks present and to designate the remedial measures necessary, the dentist should be equipped with such essential information as is determined by (1) the patient's medical and dental history, (2) digital and visual examinations, (3) roentgenograms of teeth and edentulous spaces, and (4) surveyed and occluded study casts.

MEDICAL AND DENTAL HISTORY

Any deterrent from health limitations should be considered carefully to prevent unrealistic expectations from a removable partial denture.[1] The prognosis of a removable partial denture based on the health of the patient is less complicated when health is considered in three classes. In designating which class applies, it is necessary to consider evidences of good health as assets and the presence of diseases as liabilities.

The class I patient is in robust health and is typified by healthy mucosa and lack of tooth mobility, even in the presence of occlusal disharmonies. The caries incidence is low or no history of caries is present. Barring a catastrophic disease, the properly designed restoration for this patient should not only provide years of masticatory function, but should provide preventive service. The only foreseeable limitation is noncooperation by the patient in maintenance procedures.

The class II patient is in average health and has health assets and disease liabilities that can either be corrected or eliminated. He usually demonstrates past or present caries. Gingivitis or periodontal pockets that can be eradicated are present

from the occlusal imbalance caused by loss of teeth. Successful treatment depends on the patient's cooperation in personal oral hygiene, periodontal stimulation, and prompt return for maintenance. McCracken[2] recommends full coverage of abutment teeth to prevent decalcification if observation suggests poor hygiene, because the patient will not readily change old habit patterns.

The class III patient is a poor risk with a history of predisposition to systemic disease. Correction or elimination of the liability is uncertain. Recurrent caries or periodontal pockets develop in spite of the best efforts of previous, competent, professional care. Some authorities might describe this patient as the low-resistance type. Apical abscessing and excessive periodontal pocketing, even in the presence of a balanced occlusion, is another characteristic of this class. Greater resistance to degenerative changes should not be expected when clasps are added.

Patient cooperation alone is not sufficient compensation to bring the class III patient to the level of expectation that can be enjoyed by the robust individual. In fairness to both the patient and the dentist, dental work should not be undertaken

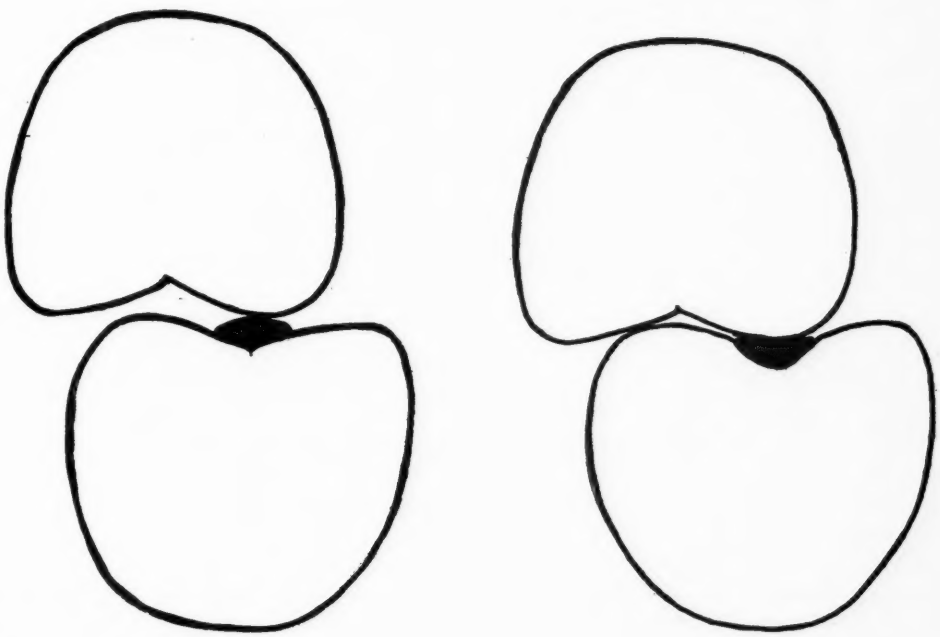


Fig. 1.—*A*, The occlusal rest increases the vertical dimension because no space has been provided. *B*, The occlusal rest preparation supplies space for the rest and permits the opposing molars to occlude without impinging on the occlusal rest.

unless the patient receives full information on the deficiencies involved. Without a mature acceptance on the part of the patient, the dentist will experience disappointment when the patient professes that he did not realize there was any speculation involved.

DIGITAL AND VISUAL EXAMINATION

The digital and visual examination is a search for tissues intolerant to stress which must be corrected to ensure success. Attention is directed to caries, erosion, abrasion, loose teeth, inflammed hypertrophic or ulcerated mucosa, knife-edge or unhealed ridges, and tori that interfere with lingual bar placement.

ROENTGENOGRAMS OF TEETH AND EDENTULOUS SPACES

Clasp position on the robust patient can be dictated more from factors of convenience, mechanics, and occlusion. The alveolar and supporting tissues of other patients may reveal evidence of previous trauma that not only precludes the possibility of using the adjacent tooth for an abutment, but may indicate its removal to restore a healthy foundation.[3]

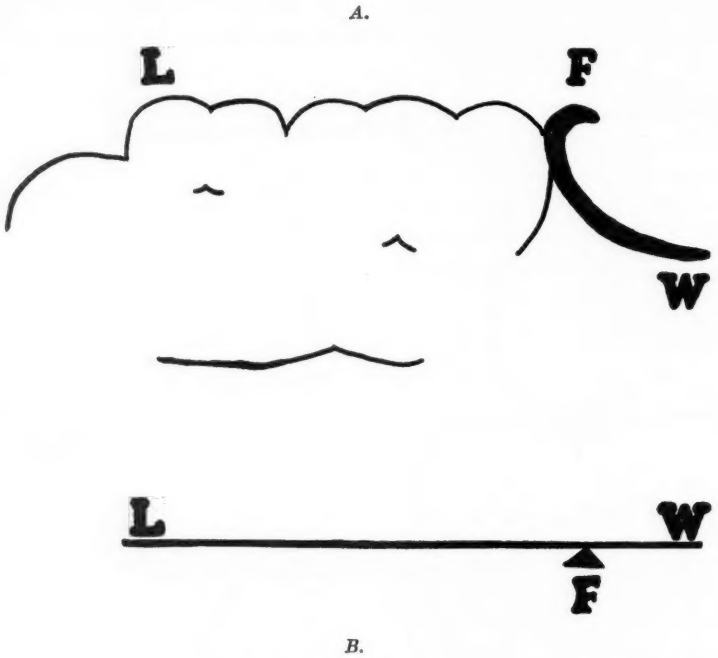


Fig. 2.—*A*, The bilateral removable partial denture in cross section is similar to *B*, the first class lever. *L* is the load, *F* the fulcrum, and *W* the work.

The combined force of occlusion, plus the clasps, must be correlated to the alveolar support of the abutment teeth. Applegate[4] and others[5-8] advise splinting the abutments when there is a doubt concerning their future stability. The elimination of sequestra, root fragments, and residual infections makes the patient's adjustment less complicated. Eliminating foci of infection aids in restoring the patient to the health optimum to facilitation of the retention of the remaining natural teeth.

The engineer, at times, cannot compensate for defects in the building site and is forced to forego its use. When the roentgenograms show such a lack of alveolar

support that splinting or stress breakers cannot supply enough relief to afford stability of the abutments, the philosophy of the engineer should be adopted and construction should be avoided.

STUDY CASTS

Surveyed study casts mounted on an articulator provide an opportunity to preview the location of the metal framework. Changes and improvements of design on the study cast are the least expensive to make. To proceed without obtaining all the information that can be gleaned from the study casts may result in a belated appreciation for M. M. House's words, "Accuracy is speed."

The most dramatic evidence of the lack of study cast planning is the increased vertical dimension caused by inadequate space for the occlusal rests on a finished restoration (Fig. 1).

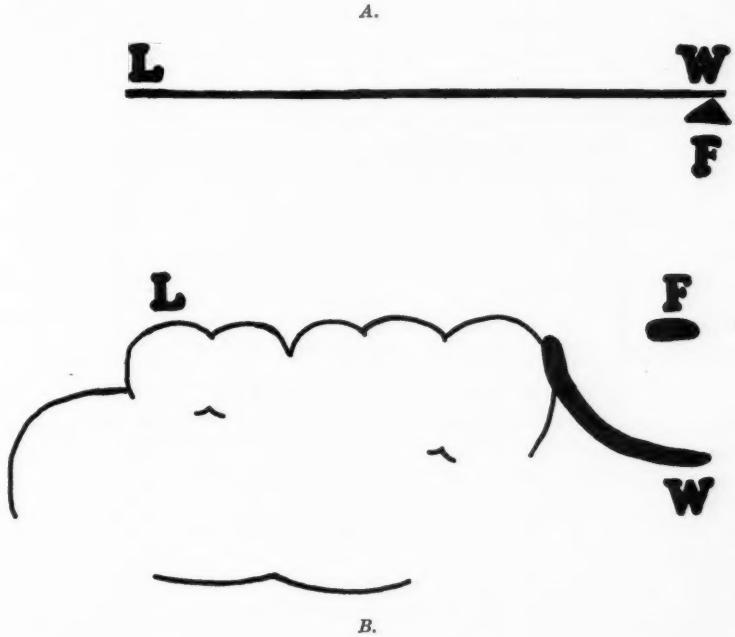


Fig. 3.—*A*, The lever is no longer first class when the fulcrum *(E)* is moved to a point equal to the work *(W)*. *B*, The occlusal rest *(F)* is moved to a point even with the end of the clasp arm *(W)* to eliminate the first class lever.

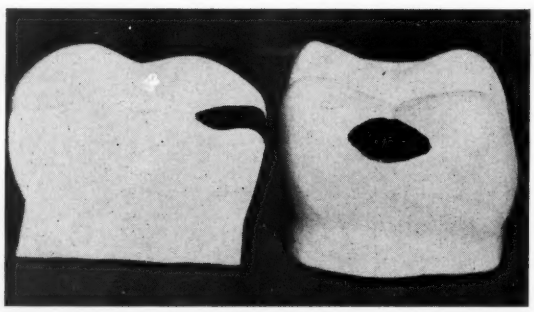
LOCATING THE OCCLUSAL REST

The occlusal rest provides support for the clasp and prevents its displacement gingivally during mastication. If both anterior and posterior abutments are present, conditions are ideal for minimizing stress on the mucosa. However, a more complex problem becomes evident with the bilateral free-end partial denture. In the effort to inhibit the vertical forces directed against the mucosa, other destructive forces are inadvertently set up.

Dentists who criticize the removable partial denture by referring to it as an orthodontic appliance[9] usually have a free-end restoration in mind. The rest on the circumferential clasp becomes the fulcrum for a first class lever exerting a transverse load on the abutment (Fig. 2). The ratio of leverage is determined by comparing the distance from the load to the fulcrum and from the fulcrum to the work. The average load-to-work ratio for the removable partial denture is four to one.

Synge[10] and DeVan[11] mention that 5.2 pounds of transverse load can cause as much periodontal displacement as 90.5 pounds of axial load. Thus, the transverse load presents a force seventeen times more potent for displacement than the axial load. If the lever advantage of four to one is added to the seventeen times greater power of transverse displacement, respect for design becomes more obvious.

The previous observation might suggest the idea that rests should be eliminated unless the lever and transverse load is broken by a stress breaker.[12,13] This sort of planning still does not offer relief to the patient with hypersensitive mucosa. The occlusal rest can still be used as a supportive stop to provide assistance to the



A. *B.*

Fig. 4.—*A*, The occlusal rest preparation is shown in cross section. *B*, The occlusal rest preparation is shown from the mesiooocclusal aspect.

hypersensitive mucosa. When the rest is moved anteriorly to a point at least equal to the most anterior part of the clasp, the rest no longer forms a fulcrum for a first class lever (Fig. 3).

The transverse force can be compensated for, additionally, by shortening the anteroposterior length of the denture base, reducing the buccolingual width of the teeth,[14] using less powerful clasps,[8] and splinting the abutments.

Boucher[15] demonstrated that normal healthy mucosa of 1.0 to 2.0 mm. thickness is only displaceable 0.08 to 0.06 mm. From this, Young[16] concludes that leverage and consideration for stress relief are unimportant.

The conclusion is dependent on the constancy of the patient's health, the lack of resorption, and the use of an ideal denture-base material. Applegate[17] states that no existing denture-base material can meet the requirements of the ideal.

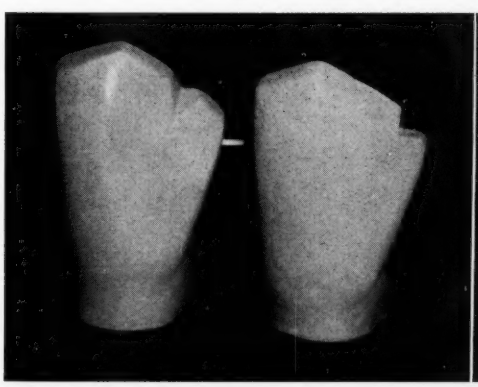
The problem of compensating for stress is increased by the patient's lack of knowledge that tissue change has occurred under the denture base. Destruction usually takes place in the investing tissues of the abutment teeth before the patient seeks help.

The development of the patient's appreciation for definite maintenance appointments should occur during the planning stage. The patient's interest or disinterest can offer a clue to the amount of his cooperation.

OCCLUSAL REST PREPARATIONS

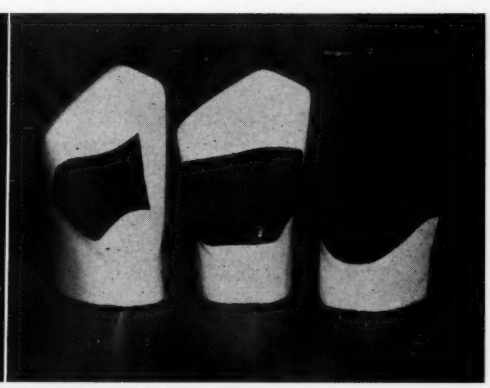
The preparation is not begun until careful consideration has been given to determination of the least stressful location for the occlusal rest. McCracken[2] and Kelly[18] point out that occlusal rest cannot be a fragile spur. The occlusal rest must have sufficient bulk for strength and be devoid of sharp angles that induce breakage in order to check the pressure of mastication.[19]

Smith and Appleby[20] recommend an occlusal rest preparation that is a saucer-like depression 1.0 to 1.5 mm. deep, triangular in general outline, and cut across the marginal ridge on the occlusal surface at right angles to the long axis of the tooth (Fig. 4). The preparation should be widest at the marginal ridge where it involves approximately one third of the buccolingual width of the tooth. From there, the sides converge to meet in the pit adjacent to the ridge. The depression should be deepest at the center and become more shallow as the sides are approached. The finished preparation should resemble the inner surface of a spoon, near its tip. The depth should allow sufficient space to provide bulk for strength when the opposing tooth is in its occluding positions. If sufficient depth cannot be obtained without penetration into the dentine, the cusp of the occluding tooth may be reduced. In



A. B.

Fig. 5.



A. B. C.

Fig. 6.

Fig. 5.—*A*, The grooved incisal rest is extended onto both the labial and lingual surfaces. *B*, The flat-shelf type incisal rest is a right angle preparation at the junction of the proximo-incisal angle.

Fig. 6.—*A*, The lingual rest is prepared for an inlay. *B*, A shelf type lingual rest is prepared on a modified three-quarter crown. *C*, A shelf type lingual rest is prepared on a three-quarter crown.

the event that space cannot be obtained from the occluding tooth, the abutment tooth is prepared for a crown or inlay. Then the occlusal rest should be prepared in the wax pattern before casting.

Rest preparations must be at right angles to the long axis of the tooth. The dentist need only be reminded of Synge's[10] seventeen-to-one ratio of resistance of the periodontal membrane to axial load as compared to transverse load. The same findings also discourage sharp angles or box formations that interject torque.

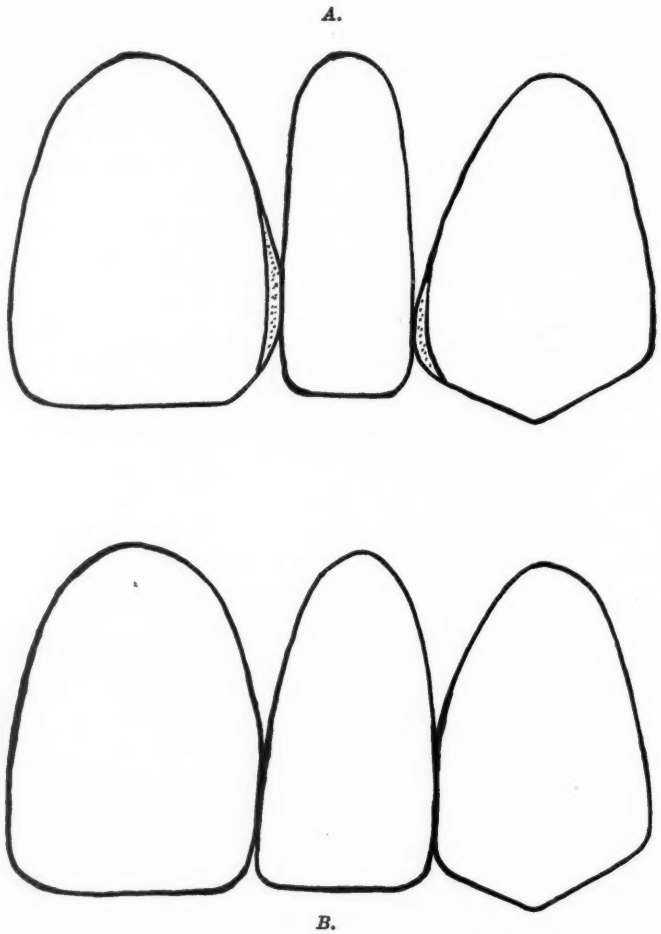


Fig. 7.—*A*, The available space causes the use of an unsightly, narrow lateral incisor replacement. *B*, The reduction of the proximal enamel on the central incisor and cuspid allows for a more natural-appearing lateral incisor.

ADDITIONAL REST PREPARATIONS

The incisal rest deviates from the occlusal preparation in that a flat cut is made into the incisal edge near the proximoincisal angle.[7] To preserve enamel, Kelly[18] uses a grooved incisal rest on lower cuspids like that introduced by Hardy[21] (Fig. 5).

Frechette[7] favors the lingual rest to the incisal rest because the force is not as far removed from the central axis. However, the insufficient thickness of enamel at the cingulum usually prevents the proper depth of preparation necessary to provide the bulk for strength. A lingual rest is best placed in an inlay or a modified or full three-quarter crown (Fig. 6). When the lingual rest is used without restorations, the preparation must be in enamel and meticulously polished.

RECONTOURING TEETH

Recontouring teeth is indicated to (1) obtain a better position for the survey line, (2) prevent the establishment of a food pocket,[22] (3) develop a more favorable path of insertion, (4) reduce the susceptibility of transverse stress, (5) provide a shape more adaptable for clasping, (6) reduce destructive inclined planes and overlapping cusps by selective grinding,[5,11] and (7) create a more esthetic appearance.

Whether the tooth is an anomaly or deficient through caries, a crown can make it suitable for clasping. The indirect technique for construction of full crowns permits their survey while in wax and thus permits one to determine and correct their parallelism with the other abutments.

Frequently, the space to be occupied by the replacement has been reduced by drifting of the adjacent teeth. Miller[23] disks the proximal walls of both adjacent teeth rather than to supply a tooth that resembles a peg. The replacement then has a more acceptable appearance (Fig. 7).

PROPHYLAXIS

Prophylaxis is indicated immediately prior to making the final impression. The final step in readying the teeth for the impression is the elimination of plaques and rough, sharp surfaces. Smooth surfaces lessen the likelihood of discrepancies in the impression.

SUMMARY

The dentist-patient relationship in removable partial denture construction is enhanced by careful attention to mouth preparation before the final impression is made. The patient's health has an effect, favorable or unfavorable, on the longevity of the prosthesis.

Mouth preparation for the removable partial denture impression is directed toward the reduction of stress in order to protect and preserve the teeth and tissues. The preconstruction planning should not only include improvement of the existing conditions, but should prevent the inclusion of new stresses.

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FIXED PARTIAL DENTURES

THE ROLE OF STUDY CASTS IN DIAGNOSIS AND TREATMENT PLANNING

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MOST DENTISTS RECOMMEND the use of study casts in diagnosis and treatment planning. Not all, however, agree on the way to use these study casts. Some dentists merely use unmounted casts to show the patient what his mouth looks like. Others, arbitrarily, articulate the study casts on a simplex articulator with or without the aid of interocclusal records. Still others locate the hinge axis, record a three-dimensional pantographic tracing of the patient's mandibular movements, and transfer their findings to a Gnathologic instrument for study. This procedure is complete but seems more time consuming and expensive than necessary for diagnostic purposes.

A functional mounting of study casts, utilizing an arbitrary face-bow transfer and an interocclusal centric relation record, is of considerable value in diagnosis and treatment planning. With this aid, the location and effect of prematurities in centric relation can be studied to gain a better understanding of the patient's occlusion.

IMPRESSIONS

Impressions of the upper and lower dental arches are made with reversible hydrocolloid. Air must not be trapped on the occlusal surfaces of the teeth. The impressions are carefully poured in artificial stone rather than plaster, because the initial tooth contacts are critical in diagnosis.

FACE-BOW TRANSFER

An arbitrary face-bow, with modeling compound on the fork, is used to orient the upper cast on the articulator. The centers of the condyles are located by palpation as the patient repeatedly opens and closes the jaws. The sense of touch more nearly approximates the location of the hinge axis than any formula for measurement.

Presented before the Greater New York Academy of Prosthodontics.

INTEROCCLUSAL RECORDS

The centric relation record must be a registration with the mouth slightly open so that the patient's habit patterns will not shunt the mandible toward a position directed by premature tooth contacts. The record must also be made during functional closure so that the muscles will pull the parts of the temporomandibular joints together and the condyles will be in a superior or bracing position in the glenoid fossae. A single closure into uniformly soft wax might record a physiologic rest or "dropped" position of the condyles in which the mandible is not in centric relation.

The objectives of the centric relation record are attained by using a triple thickness of hard baseplate wax. The wax is held by its "anterior" portion in a water bath at about 130° F. The "posterior" portion of the wax is softened considerably more than the anterior part, which is out of the water most of the time. Thus, anterior resistance is provided. This resistance tends to act as a fulcrum which aids in obtaining a registration of the condyles in the superior position. The hardened wax also provides resistance to penetration, thus preventing interference from habit patterns.

The wax is placed over the maxillary teeth, and the mandible is guided (not pushed or forced) into repeated closures. The wax is removed, allowed to cool (not chilled), and replaced in the mouth several times. The occlusal indentations are relieved and relined with a soft wax such as Aluwax. The wax record is replaced in the mouth, and the mandible is again guided into repeated closures. The wax is cooled, and when no distortion can be detected on closure, the record is accepted. Second and third centric relation records help to check the accuracy of the first record. A protrusive record is made in a straightforward, protruded position.

MOUNTING THE CAST

The upper cast is mounted on an adjustable articulator with the face-bow record. The cast can be seated accurately into the modeling compound, and the condyle rods of the face-bow are adjusted inward equal distances to meet the articulator. This method is not as accurate as that of locating the hinge axis and transferring it with a hinge-bow; however, it is less time consuming and costly. This approximation is adequate for diagnostic purposes, except for patients with extremely asymmetric condyles. The Hanau model H-2-X can be used for people with asymmetric faces, because this instrument has an extendable axis shaft. The use of this instrument rules out one additional variable.

The lower cast is positioned in the correct relation to the upper cast by means of the centric relation record and is mounted on the articulator with artificial stone or a good grade of plaster of Paris with little setting expansion. The condyle paths are adjusted by means of the protrusive record. The articulator can be closed on nearly the same arc as the closing arc of the mandible. We are aware that only an arbitrary axis has been located and some discrepancy has undoubtedly resulted. The habit patterns of the patient have been eliminated, however, and the occlusal relations can be studied accurately.

MOUNTING ACCURACY

A patient was selected to test the accuracy of this type of mounting. The patient had a symmetric face and had been conditioned for centric relation. The casts were mounted using the procedure described. Over a period of 4 weeks, about twenty-five interocclusal centric relation records were made using thicknesses of wax that ranged from one to eight layers. Also, several artificial stone interocclusal records of various thicknesses were made. The patient's centric occlusion was definitely not in harmony with centric relation, since there was an extreme prematurity in the right bicuspid region. Nevertheless, the mounted casts accepted all of the subsequent centric relation records of either wax or stone.

These results were verified using the split-cast method described by Lauritzen.[1] This method consists of grooving the upper cast and lubricating it before mounting. Other centric relation records are verified by separating the scored upper cast from its mounting, placing the cast in the new record, and closing the mounting upon it. If the mounting goes precisely into place, the face-bow transfer and centric relation record must be correct.

Using this split-cast technique, a slight hairline discrepancy was noted with most of the other centric relation records. It is presumed that this error was due to the use of an arbitrary axis rather than the hinge axis. All records were close, however, which lends support to the use of this type of mounting procedure for diagnostic purposes.

CENTRIC RELATION

The technique described is predicated on a concept of centric relation. It is not my purpose to add to the semantic confusion surrounding the myriad definitions of centric relation. However, I believe that centric relation results from definite and reproducible positions of the condyle and menisci in the glenoid fossae. For clinical purposes, centric relation is constant regardless of the vertical dimension within the limits of pure rotation of the condyle. Centric relation represents a usable mandibular position, for it is the *only* position that can be recorded repeatedly. Therefore, we must record it as a starting point, for without it we cannot orient one jaw to the other for either diagnostic or treatment purposes.

CONDITIONING THE PATIENT

Making the centric relation record is not always an easy matter. Often, the patient must be conditioned for centric relation. There are several methods of conditioning the patient, any or all of which may be used. First, the teeth may be prepared and temporary restorations (preferably gold) that occlude in a position close to centric relation may be constructed. This will break the old habit patterns, and the final centric relation is recorded before new habit patterns are deeply rooted.

Another method entails the use of a splint which allows only the anterior teeth to contact. With no posterior tooth contacts, the mandible will usually be pulled naturally into centric position by the musculature in a matter of a few days.

A third method is the use of regular jaw exercises, as described by Boos,[2] to stretch and relax the muscles of mastication. After such exercises, the musculature is less likely to "fight the dentist" when centric relation is being obtained.

SUMMARY

The use of study casts is essential for proper diagnosis and treatment planning. An accurate method of mounting the study casts utilizing an arbitrary facebow and an interocclusal centric relation record is described. It may be as important to record centric relation for purposes of diagnosis as it is for treatment of patients with malocclusions.

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PHYSIOLOGIC OBJECTIVES OF RECONSTRUCTION TECHNIQUES

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THE DENTAL PROFESSION is now more interested in improved methods of reconstruction than at any other time in its history. One can hardly read a journal dealing with restorative dentistry without seeing some reference to axes of rotation and various articulators. Some claim that a particular articulator is the panacea for all problems. In comparison, less is written about the shortcomings of articulators or even basic purposes of laboratory tools from a physiologic point of view.

This article deals with some of the basic physiologic objectives behind the mechanical techniques used in reconstruction.

CONCEPT OF ORAL FUNCTION

The term "function" as applied to the mouth includes everything the patient does with his mouth. Mastication, then, is not completely synonymous with oral function but only a part of it. Mastication takes place approximately 1 hour a day. When the distinction is made between masticatory function and nonmasticatory function, many of the conflicting theories on occlusion find their rightful place.

Mastication.—Whether cusps penetrate the bolus all or part of the time or even not at all is really academic. Those who claim the teeth do not meet in mastication[1] readily agree that the teeth do meet in centric occlusion during normal deglutition. Agreement is almost universal that evenly distributed contact in centric occlusion is desired. Such universal agreement on eccentric contact is not possible at this time.

Nonmasticatory Function.—Most patients show signs of tooth-to-tooth contact in eccentric positions by producing sharply delineated wear facets.[2] Tooth-to-tooth contact causes this type of wear rather than the rounded surfaces produced by food abrasion. The proponents of the theory that teeth do not meet in mastication, except during deglutition, imply that eccentric cuspal harmony is for the most part unnecessary. If this were true, only a hinge articulator would be needed for laboratory procedures, and the physiologic objective would be to provide only good centric occlusal contact. Occlusal equilibration for periodontal therapy would include only preliminary grinding and the correction of centric occlusion.

Therapy should be directed to include the 23 hours of nonmasticatory function. It is during this time that most eccentric tooth-to-tooth contact occurs.

THE ROLE OF THE ARTICULATOR

The physiologic objective of the adjustable articulator is to provide a means for the construction of dental restorations that results in the distribution of occlusal

pressure (1) in centric occlusion when the patient swallows food or saliva and (2) in eccentric contact during bruxism or when the patient clenches the teeth or makes tooth-to-tooth contacts while chewing soft foods.

Adjustable articulators do *not* attempt to imitate mandibular movements during mastication. The degree of vertical opening is greater in a lateral excursion during mastication than in a movement of bruxism. In a limited range of motion, the condyles may move in similar three-dimensional paths in mastication and in bruxism even though the degree of vertical opening is different. There is theoretic[3,4] and practical[5] evidence that a change in incisal guidance does not necessarily change the condylar paths.

Theoretically, then, how can the use of any adjustable articulator that records and imitates the type of movements in bruxism rather than actual masticatory movements be justified? First, the difference in the three-dimensional condylar paths in bruxism versus mastication is due to the relative difference in the protrusive component rather than the difference in vertical opening. Second, a tough bolus separates the teeth enough to reduce the cuspal incline influence. Third, when the teeth do penetrate or almost penetrate the bolus in their movement toward centric occlusion, the cuspal inclines dominate the mandibular movements. This part of the masticatory cycle closely resembles the bruxism movements which are used to record condylar movements. Fourth, during nonmasticatory function (clenching, bruxism, and occasional occlusal contacts) the occlusal and condylar relationships on the articulator most accurately resemble the physiologic conditions.

The adjustable articulator, then, does provide the mandibular position of centric occlusion during normal deglutition and can imitate only *some* of the mandibular movements that are similar to bruxism. The degree of accuracy in obtaining these objectives depends on the methods used.

HINGE VERSUS ADJUSTABLE ARTICULATORS

The adjustable articulator is of great service, because it is better equipped than a hinge articulator to produce even occlusal pressure during contacts in centric occlusion. Any slight change in vertical dimension produces less occlusal disharmony by virtue of the hinge axis or face-bow mounting.[6] Due to the "pure" protrusive and lateral records obtained in border movements, the plane of occlusion, sagittally and transversely, as well as the related occlusal cusp inclines can be oriented on the articulator.[3,4]

One of the criticisms of adjustable articulators that requires evaluation is that *only pure protrusive and lateral movements of the bruxism type are recorded and imitated.* Physiologically, the teeth can be moved in infinite combinations of protrusive and lateral excursions rather than purely one or the other. Individual habit patterns also have a bearing on mandibular movements. Furthermore, a tough bolus can prevent cuspal contact. It is impossible and unnecessary to record all of these possible movement patterns. Extremely accurate imitation of the "pure" or border protrusive and lateral condylar paths is possible with a Gnathologic instrument.[7] Approximate condylar paths are obtainable with the Hanau type of adjustable articulator.

Even if it were possible to imitate the complete range of bruxism movements from pure lateral to pure protrusive excursions, it would be impossible to create restorations that would always be in harmony for any combination of these movements. Certainly, no natural occlusion has this condition. The patient's neuromuscular reflexes seem to establish paths of protrusive and lateral excursions that produce the least trauma. Clinical physiologic evidence justifies the establishment of basically one harmonious path for each lateral and protrusive movement similar to bruxism. It follows that an adjustable articulator is equipped to aid in this objective, since its records are based on pure protrusive and lateral mandibular movements.

MASTICATION AND THE ARTICULATOR

When tough foods prevent actual tooth contact, the orientation of the occlusal plane and the cusp inclines is still of primary importance. As the teeth approach centric occlusion, the cuspal inclines exert guiding influences because of the noncompressible food between them. Unfortunately, this point is usually neglected. When softer foods are chewed, tooth contact is possible. The neuromuscular reflexes avoid trauma and usually establish patterns of motion in relation to the existing cusp inclines.

PHYSIOLOGIC MOTION IN RELATION TO MECHANICAL MOTION

Only a small part of physiologic mandibular motion can be utilized for laboratory imitation. Most mandibular movements have a rotational pattern, that is, the motion is part of a circle or ellipse. Spee's curve and the transverse curve are examples of anatomic form dictated by the rotational patterns of physiologic motion.

Physiologic rotational motion is produced by the coordinated action of muscles and joints. As integral parts of these coordinated rotational motions, various physiologic axes of rotation must exist. Even though the patient does not have mechanical axes of motion, he does have "imaginary" or physiologic ones. Since rotational motion and axes of rotation are part of the same thing, it is more correct to use the term "physiologic axes of rotation."

The mechanical axes of rotation on a machine are substituted for the physiologic axes of rotation of the patient to permit imitation of basic mandibular motions for laboratory purposes. The resultant laboratory motion is equivalent to the physiologic motion if the instruments are accurate. The substitution of the mechanical axes of rotation for the physiologic axes eliminates the impossible task of duplicating the actual anatomic and physiologic conditions of each patient.

Three-dimensional mandibular motion must have axes of rotation related to each of the three planes. The three planes are the sagittal, the frontal, and the transverse. The mandible transverses all three planes in its lateral movements. Only in opening and closing jaw movements is it possible for the mandible to stay in one plane (sagittal).

ROTATION

Transverse Hinge Axis.—There is one physiologic transverse hinge axis which passes through both condyles.[6] The transverse hinge axis is associated with rotation of the mandible in the vertical (sagittal) plane (Fig. 1). Due to condylar

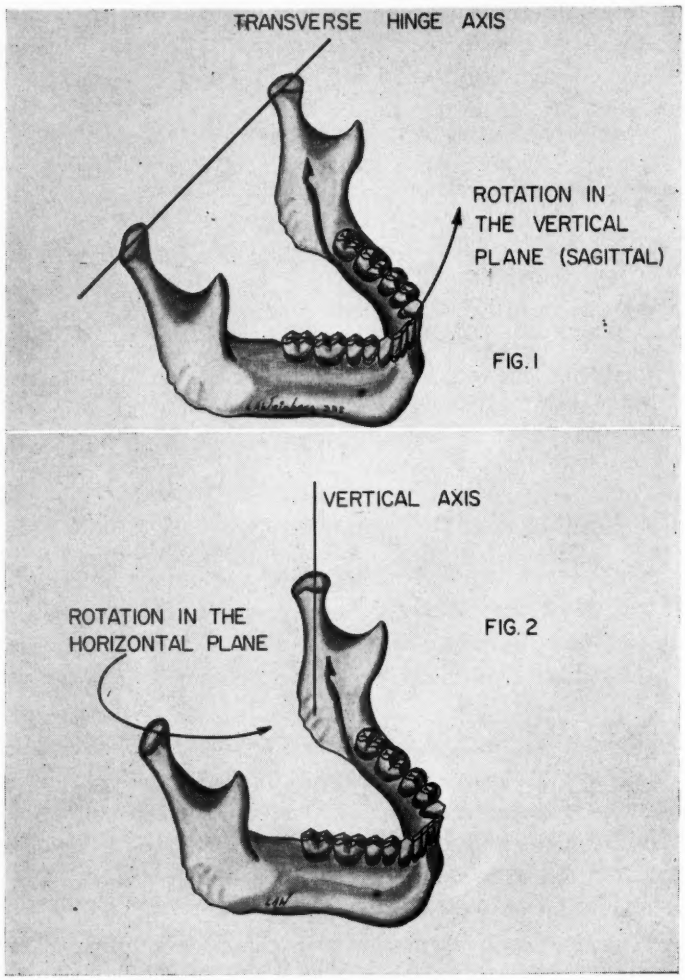


Fig. 1.—There is one physiologic transverse hinge axis which passes through both condyles. This axis is associated with rotation of the mandible in the vertical (sagittal) plane.

Fig. 2.—The physiologic vertical axis of rotation is associated with rotation in the horizontal (transverse) plane and is located through the left working condyle.

asymmetry, the sagittal plane of motion may not be exactly parallel with the arbitrary vertical plane of the face. During normal opening, this slightly "off-center" sagittal plane of motion remains perpendicular to the transverse hinge axis[6] and does not imply the self-contradictory description of two transverse hinge axes.[7]

Marked off-center opening is due to unilateral condylar restriction of motion. A lateral component is produced, and the opening motion is no longer in one plane because of temporomandibular dysfunction.

During normal opening and closing, the physiologic transverse hinge axis itself moves downward and forward creating an elliptic arc of rotation of the body of the mandible. The transverse hinge axis can remain in one position without translation with trained opening and closing movements. The mandibular motion for this movement is circular. This method is used to locate the terminal position of the transverse hinge axis in Gnathology.[7] The Hanau (Snow) face-bow uses an anatomic average location of the physiologic transverse axis determined by measurement.

Vertical Axis of Rotation.—The physiologic vertical axis of rotation is associated with rotation of the mandible in the horizontal (transverse) plane. The verti-

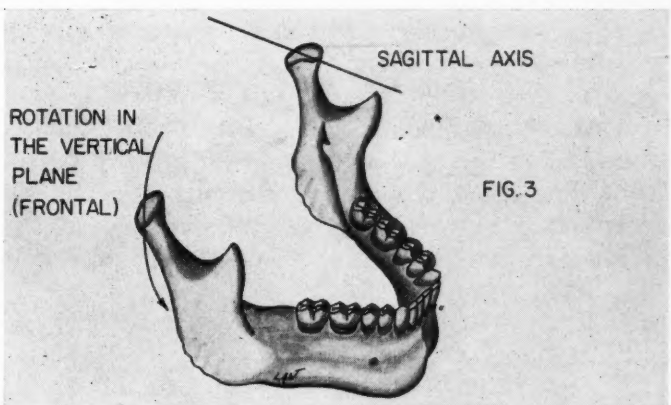


Fig. 3.—The physiologic sagittal axis of rotation is associated with rotation in the frontal plane. The right balancing condyle rotates about the sagittal axis located through the left working condyle.

cal axis is located through the working condyle (Fig. 2). The rotational motion is always perpendicular to the axis by definition. There is a physiologic vertical axis for each working condyle; of course, only one functions at a time.

The distance between the fixed uprights on the Hanau articulator represents the average intercondylar or intervertical axis distance (about 110 mm.). If a Gnathologic instrument is used, the individual intervertical axis distance is transferred to the articulator by means of extraoral tracings of eccentric mandibular movements which are etched in glass.

Sagittal Axis of Rotation.—The physiologic sagittal axis of rotation is associated with rotation of the mandible in the vertical (transverse) plane (Fig. 3). The amount of rotation in the vertical (frontal) plane depends on the degree of downward movement of the balancing condyle which is dictated by the anatomy and musculature of the temporomandibular joint.

LATERAL MOVEMENTS

Transverse Hinge Axis During Lateral Movements.—The transverse hinge axis is one continuous axis common to both condyles (Fig. 4). During a lateral mandibular excursion, the physiologic transverse hinge axis on the balancing side moves anteriorly at an angulation, usually, to the horizontal plane. On the working side the transverse axis often remains at or near the original level. This relatively unilateral downward and forward movement of the physiologic transverse hinge axis on the balancing side is commonly referred to as the balancing condyle inclination. Since the balancing condyle inclination is usually greater than that of the working side, the balancing cusp inclines are correspondingly more inclined. The same situation usually exists bilaterally and the typical transverse curve of occlusion is formed.[4]

Vertical Axis During Lateral Movements.—The superior half of the vertical axis rotates medially and anteriorly during lateral mandibular excursions (Fig. 5). There is a corresponding inferior and slightly inclined movement of the horizontal (transverse) plane of motion which must always be perpendicular to the vertical axis of rotation. In other words, a change in the plane of motion is always accompanied by an appropriate change in its axis of rotation, because the two are always fixed in relation to each other.

Sagittal Axis During Lateral Movements.—The anterior half of the sagittal axis rotates laterally and inferiorly during lateral mandibular excursions (Fig. 6). There is a corresponding anterior and slightly inclined movement of the frontal plane of motion which remains perpendicular to the sagittal axis of rotation.

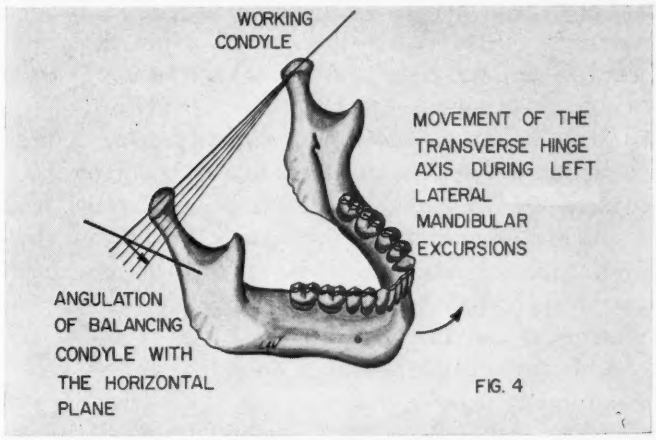
COORDINATED ROLE OF PHYSIOLOGIC AXES DURING LATERAL MANDIBULAR MOVEMENTS

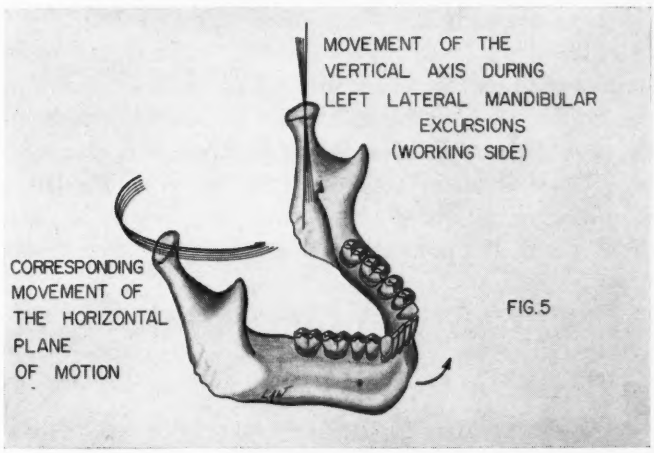
The paths of movement of the working and balancing condyles and the intimate three-dimensional relationship of these two guidances of jaw movements are seen in Figs. 7, 8, and 9. Theoretically, the three basic working condyle movements are (1) rotation with little lateral movement, (2) rotation with lateral movement at zero-degree inclination, and (3) rotation with inclined lateral movement. These condylar movements are described in terms of the physiologic axes of rotation and the three-dimensional effect on the paths of motion of the balancing condyle. Clinical experiments with the Gnathoscope show that the working condyle not only can rotate with little lateral movement, but can move directly laterally or at some angulation.[8] The working condylar movement varies in character with each patient.

The Hanau (model H) type of adjustable articulator can only imitate a working condyle that rotates and moves laterally at zero-degree inclination.

Rotation of Working Condyle.—The downward component of the balancing condyle initiates rotation about the sagittal axis in the working condyle (Fig. 7). Lateral movement of the jaw usually requires some opening; therefore, there is a rotation in the vertical (sagittal) plane about the transverse hinge axis.

The three axes of rotation remain in a fixed perpendicular relationship to each other during mandibular movement. The coordinated lateral movement of the mandible causes the three physiologic axes of motion to rotate. As a result, the





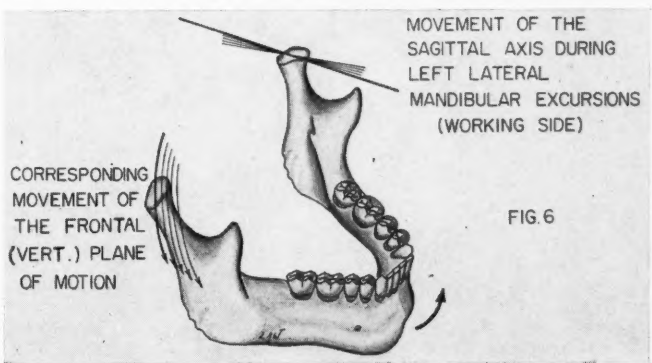


Fig. 4.—During a left lateral mandibular excursion, the physiologic transverse hinge axis on the balancing side moves anteriorly at an angulation, usually, to the horizontal plane. On the working side, the transverse axis often remains at or near the original level.

Fig. 5.—During a left lateral mandibular excursion, the superior half of the vertical axis rotates medially and anteriorly. There is a corresponding inferior and slightly inclined movement of the horizontal (transverse) plane of motion.

Fig. 6.—The anterior half of the sagittal axis rotates laterally and inferiorly during a left lateral mandibular excursion. There is a corresponding anterior and slightly inclined movement of the vertical (frontal) plane of motion.

lateral movement of the mandible is not limited to one plane, but there is a three-dimensional movement related to all three planes. Only the pure opening and closing movement can be in one plane, and in this movement only translation of and rotation about the physiologic transverse hinge axis take place.

Movement of the Planes of Motion.—The downward movement of the horizontal plane of motion, as well as the forward movement of the vertical plane of motion, produces the intersection of these planes on the transverse hinge axis (Fig. 7). A line joining these intersections illustrates the path of the balancing condyle in three dimensions. There are an infinite number of planes of motion each corresponding to one of the infinite number of locations of the axes during lateral mandibular movements.

Rotation and Lateral Movement of Working Condyle.—Close examination of the vertical and sagittal axes reveals that they do not remain parallel to their original orientation as they move laterally (Fig. 8). Indeed, as rotation of the mandible takes place about each axis, the axis itself must rotate.

Movement of an axis of rotation itself can be difficult to visualize. It is confusing enough to imagine motion about an axis of rotation in one plane. Perhaps it might help to restate that the plane of motion is always perpendicular to the axis of rotation of that plane. It follows that for motion in more than one plane, the various physiologic axes of rotation must move. Since lateral excursions of the mandible concern all three planes and the three axes are always perpendicular to each other, the motion is accomplished by a combination of move-

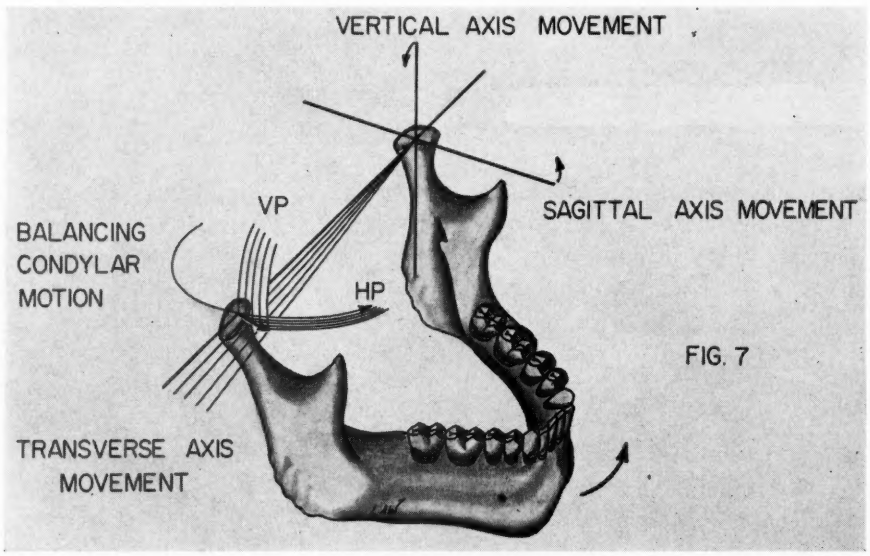


Fig. 7.—Rotating working condyle with little lateral movement. On the working side (left) the vertical and sagittal physiologic axes meet at a point on the transverse hinge axis. As the mandible rotates to the left about the vertical axis, the balancing condyle on the right side moves forward, downward, and medially. *HP*, the corresponding horizontal plane of motion; *VP*, the corresponding vertical plane of motion produces the intersection of these planes on the transverse hinge axis. A line joining these intersections illustrates the path of the balancing condyle in three dimensions (arrow).

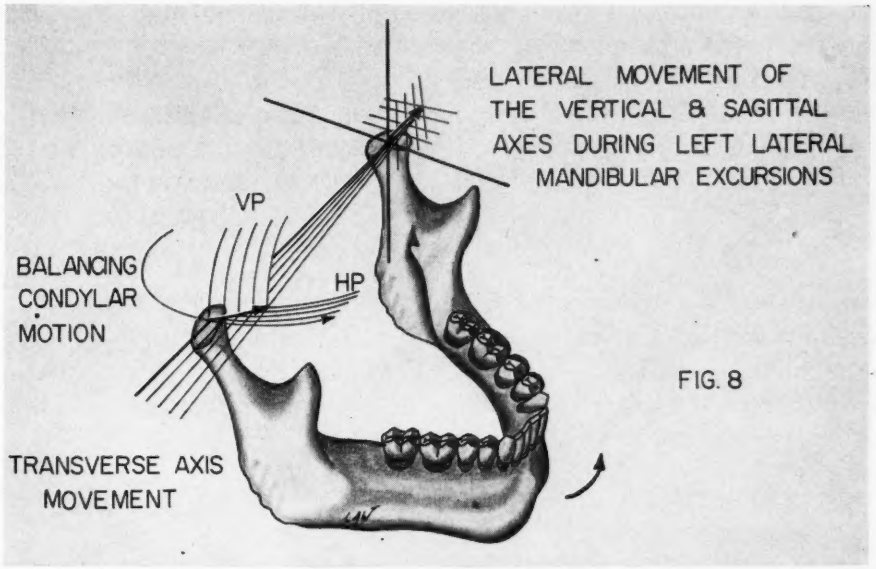


Fig. 8.—Rotating and laterally moving working condyle. The lateral movement (on the working side) of the vertical and sagittal axes during left lateral mandibular excursions is represented by the small crossed lines. Distances are exaggerated for clarity. As the sagittal axis rotates and moves laterally on the working side, the corresponding vertical plane of motion *(VP)* of the balancing condyle moves more medially than in Fig. 7. The horizontal plane of motion *(HP)* of the balancing condyle also must follow downward and medially, corresponding to the rotation and lateral movement of the vertical axis. The transverse hinge axis moves downward and forward unilaterally on the balancing side (right), corresponding to the path of the balancing condyle. A line joining the intersections of the vertical and horizontal planes of motion with the transverse hinge axis plots the three-dimensional balancing condyle path (arrow).

ment and rotation of the three axes themselves. The infinite number of possibilities of physiologic paths of mandibular movements are produced simply by changing the relationship of the degree of rotation about each axis to the movement of the axis itself.

Rotation and Inclined Lateral Movement of Working Condyle.—The rotation and inclined lateral movement of the vertical and sagittal physiologic axes during left lateral mandibular excursions are shown in Fig. 9. As one might expect, the degree of inclination and movement of this lateral shift of the working condyle is usually less than the inclination of the balancing condyle.

The three different balancing condyle paths are seen superimposed in Fig. 10.

REQUIREMENTS OF THREE-DIMENSIONAL MOTION

A solid object must have at least three points of guidance to orientate its motion in space. The condyles act as two of the required points of guidance. When the teeth are in contact, they take precedence over the muscle complex (entire mandibular musculature) as the third point of guidance.[3] The total effect of tooth-to-tooth contact can be measured at the incisors and is referred to as the incisal guidance.

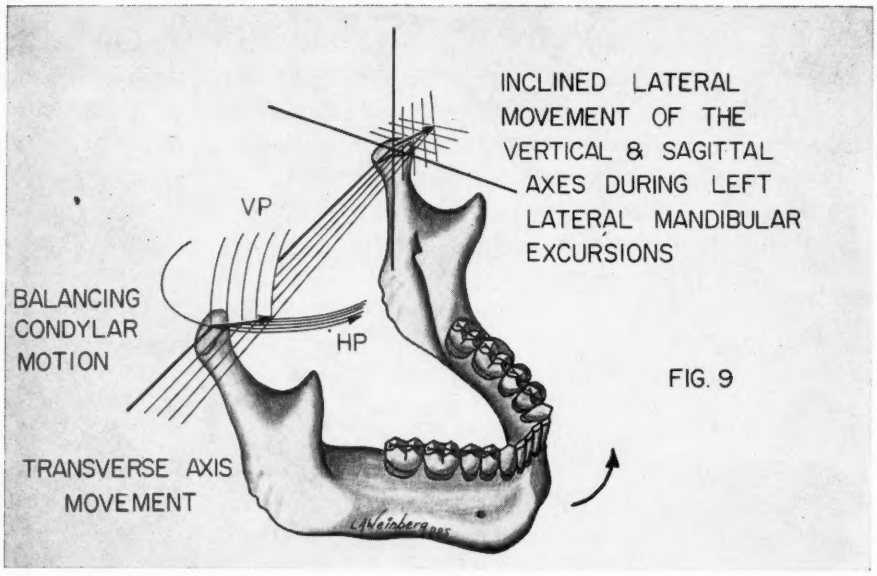

INCLINED LATERAL MOVEMENT OF THE VERTICAL & SAGITTAL AXES DURING LEFT LATERAL MANDIBULAR EXCURSIONS
VP
BALANCING CONDYLAR MOTION
HP
FIG. 9
TRANSVERSE AXIS MOVEMENT

Fig. 9.—Rotation and inclined lateral movement of the working condyle. The transverse hinge axis on the balancing side (right) moves downward and forward during a rotating and inclining lateral movement of the working condyle. On the working side (left), the transverse hinge axis no longer remains on the original level but moves downward corresponding to the degree of inclined movement on the working side. A line joining the intersections of the vertical *(VP)* and horizontal *(HP)* planes of motion with the transverse hinge axis illustrates the three-dimensional path (arrow) of balancing condyle motion. This path is somewhat similar to the balancing condyle path which is produced when the working condyle rotates and moves laterally with no inclination (see Fig. 8).

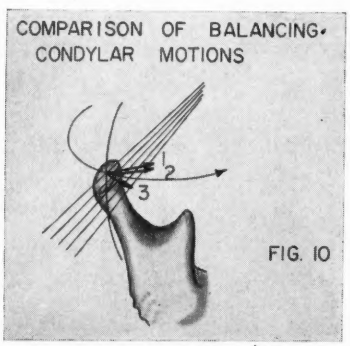


Fig. 10.—The three different balancing condyle paths are superimposed on each other. The transverse hinge axis and the vertical and horizontal planes of motion are indicated for spacial orientation. Balancing condyle path *3* represents the most anterior path produced by a rotating working condyle with little lateral movement (as seen in Fig. 7). Balancing condyle path *2* represents a more medial direction produced by a rotating working condyle with inclined lateral movement (as in Fig. 9). Path *1*, which is the most medial of the balancing condyle movements, is produced by a rotating working condyle which move laterally at zero-degree inclination (as in Fig. 8).

Physiologically, the mandible has many more than the minimum three points of guidance. The joints, muscles, and teeth are coordinated by a complicated system of neuromuscular reflexes. For laboratory purposes, however, the minimum three points of guidance, namely the two condylar paths and the incisal guidance, permit an imitation of pure protrusive and pure lateral bruxism motions for reconstructive procedures.

INCISAL GUIDANCE

The incisal guidance on the articulator is composed of three guide planes. One guide plane, related to protrusive movement, has its angulation in the vertical (sagittal) plane of motion (Fig. 11). The other two guide planes are related to lateral movements and have their angulation in the horizontal plane of motion

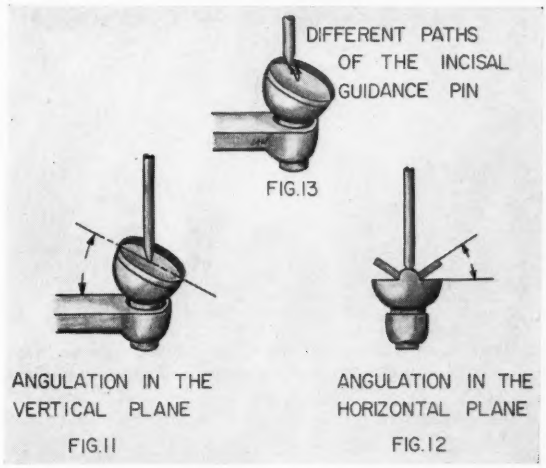


Fig. 11.—The incisal guide plane related to protrusive movement has its angulation in the vertical plane of motion.

Fig. 12.—Two of the three incisal guide planes of motion are related to lateral movements and have their angulation in the horizontal plane of motion.

Fig. 13.—The incisal guidance pin develops different paths of movement with the same condylar settings by variation in the relationship of the three guide planes of motion.

(Fig. 12). By varying the relationship of these three guide planes, the incisal guidance pin develops different paths of movement with the same condylar settings (Fig. 13).

Whenever possible, the patient's incisal guidance should be transferred to the articulator by the use of acrylic resin copings made directly from the mouth. Deviations from the patient's incisal guidance should be made only after the utmost consideration of the effect on the muscle complex and the condylar paths. If the condylar paths are judiciously imitated, as in Gnathology, changes in the incisal guide planes will *not* necessarily produce measurable changes in the condylar paths.[3-5] However, the changes in the incisal guide planes will alter cuspal

inclination and, therefore, the movement of the body of the mandible itself. Problems in the muscle complex may develop if the physiologic tolerance is exceeded.

If a Hanau model H adjustable articulator is used, changes in the incisal guide planes not only produce alterations in the cuspal inclines and their relation to the muscle complex, but in the condylar paths as well. This occurs because the condylar paths on the Hanau articulator are *approximations* of the physiologic condylar movements. With either type of articulator, occlusal equilibration[9-13] is necessary in the mouth after completion of the laboratory phases of fixed or tooth-supported removable partial dentures. Construction on a Hanau articulator requires more intraoral adjustment. Construction of these restorations on an articulator with only hinge movement practically precludes harmonious eccentric contacts.

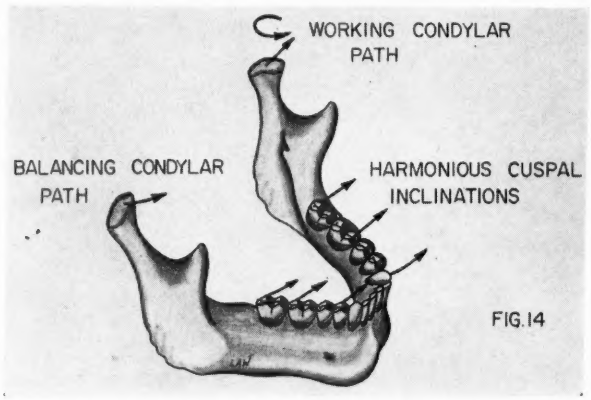


Fig. 14.—The cusp inclines must be constructed to harmonize with the specific three-dimensional working and balancing condyle motions and the incisal guide planes of the articulator.

RECONSTRUCTED INCLINES AND PHYSIOLOGIC HARMONY OF THE CONDYLAR PATHS AND PERIODONTAL SUPPORT

The imitated condylar paths and the incisal guide planes provide the minimum requirements of three points of guidance. A plane of occlusion and cuspal inclines that harmonize with these three guidance factors in centric occlusion and pure protrusive and pure lateral gliding movements can be constructed. Once cuspal inclines are constructed, they form definite pathways that dominate physiologic mandibular movement to conform similarly to the three-dimensional movement on the articulator.

Unless an accurate three-dimensional relationship of the three guidance factors is produced on the articulator, the resulting restorations will not be in harmony with the periodontal support, muscle complex, and temporomandibular joints (Fig. 14). Fixed restorations constructed on a Hanau (model H) articulator require more occlusal adjustment in the mouth because the condylar relationships and paths are "estimates." Similar restorations constructed on a Gnathologic instrument require minor intraoral equilibration.

Fortunately, Nature usually provides a great deal of tolerance. The restorations that fail often represent a smaller physiologic margin with too great a therapeutic license.

SUMMARY

The physiologic three-dimensional movements of the mandible are best described in terms of the physiologic axes of rotation and their associated planes of motion. The various types of working condyle motions (mainly rotation, rotation with lateral movement, and rotation with inclined lateral movement) have a profound effect on the three-dimensional path of the balancing condyle and the resulting cuspal anatomic condition. During laboratory construction, the individual condylar paths and the incisal guidance determine the orientation of the occlusal plane and the cusp inclines.

Only the Gnathologic type of instrument accurately imitates the individual spacial condylar relationships. From a practical standpoint, however, the Hanau type of adjustable articulator affords most dentists an excellent instrument for the construction of harmonious restorations if its limitations are understood. Some intraoral occlusal equilibration is necessary with either instrument.

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PRIMARY SUBSTRUCTURES AND REMOVABLE TELESCOPIC SUPERSTRUCTURES IN DENTAL RECONSTRUCTION

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THE TELESCOPIC TYPE OF FULL CROWN has been described previously.[1,2] It consists of a primary structure (thimble) combined with a secondary crown which fits the thimble. The telescopic crown can be used to overcome some of the problems encountered when full crowns are required for reconstruction purposes.

PROBLEMS ENCOUNTERED

Reconstructive procedures entail either permanent or temporary cementation of the crowns. Permanent cementation often presents a problem if removal of the restoration becomes necessary because of pulpal or periodontal problems. The removal of a permanently cemented fixed partial denture generally causes mutilation of the restoration and requires time and expense for replacement.

A conservative approach has been advocated which entails the use of temporary rather than permanent cement.[3] Thus, the restoration may be removed for the alleviation of symptoms or repairs to individual teeth or tissues. However, repeated temporary cementation also introduces problems. Temporary cement lacks the rigidity and durability to meet the conditions of stress and flexure to which lengthy multiunit restorations are subjected. In addition, leakage under temporarily cemented crowns introduces the risk of caries, and the restorations must be inspected periodically.

Recession of the gingivae and exposure of the root surface is another problem encountered with the use of full crowns, regardless of whether permanent or temporary cementation is used. The resultant caries in the cementum and unesthetic appearance are difficult to correct without removing and remaking the crowns or the entire multitooth splint.

Because of these problems, we developed a technique which combines the use of the telescopic crown with recent improvements in prosthetic procedures. This technique combines the advantages and minimizes the pitfalls of permanent and temporary cementation. The technique consists of a primary substructure (thimble) and a secondary superstructure (crown) which is fitted on the substructure. This technique is primarily intended for large multiunit splints although it may be used for small restorations.

Read before the Annual Convention of the Canadian Dental Association, Halifax, Nova Scotia.

THE PRIMARY SUBSTRUCTURE (THIMBLE)

The teeth are prepared for full crowns using either a full or partial shoulder preparation (Fig. 1). Copper-band impressions are made immediately after completion of the preparations, and a splint of cold-cure acrylic resin is prepared as a temporary covering for the involved teeth. A full wax impression is made in a tray filled with softened wax. This impression is relined with blue inlay wax for better detail. The dies, copper plated and trimmed, are inserted into the impression, and a cast is poured.

After the cast is poured, the primary thimble is waxed and the shoulder is carved in the wax. The shoulder in the thimble should be slightly above the gingival tissue on the lingual and interproximal surfaces. On the buccal surface, the

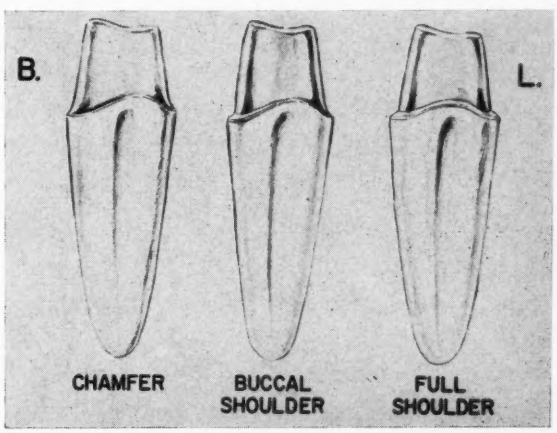

Fig. 1.—Different types of preparations are used for full-crown construction.

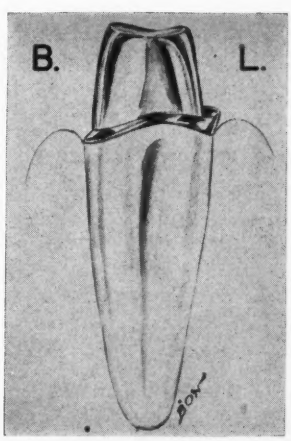

Fig. 2.—The shoulder of the primary thimble is grooved to minimize rotation and improve retention.

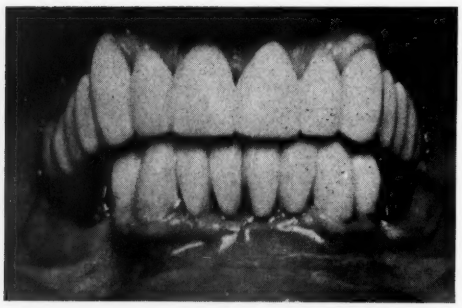

Fig. 3.—The acrylic resin superstructure is tried in the mouth.

chamfer blends with the interproximal shoulder. The chamfer is at an approximate 45-degree angle (Fig. 2). Shoulders placed high in the direction of the crown on the interproximal surface permit a broad shoulder without impinging on the gingival papilla. The buccal chamfer should not be as wide as the lingual or interproximal shoulder.

The shoulder in the thimble is grooved lingually and interproximally to obtain better interlocking. A straight-butt shoulder is less retentive and introduces a greater risk of washout of the temporary cement. Frequently, preparations may be almost perfectly round, which allows the superstructure to rotate on the primary crown. Grooving the shoulder diminishes the likelihood of rotation (Fig. 2).

A surveyor is used to obtain the correct taper of the thimble. The taper corresponds approximately to that of a tapered fissure bur. While the taper should be minimal, this is not always possible or desirable.

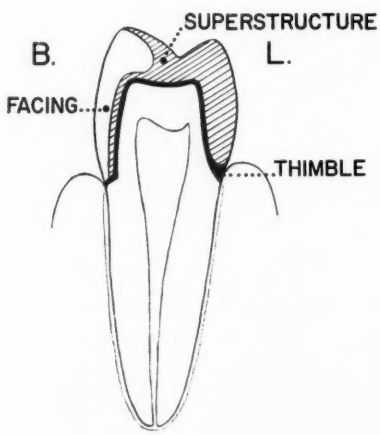

Fig. 4.—The cross section of a telescopic crown with an acrylic resin facing.

The thimble is completed on the die-bearing cast and rechecked with the surveyor to ascertain the absence of undercuts on the axial walls. This procedure

avoids major alterations to the thimble on the master cast. Then, the primary thimble is cast in gold.

The primary thimbles are seated in the mouth on the prepared teeth. To ensure their correct seating, openings are made on their lingual surfaces. Inter-

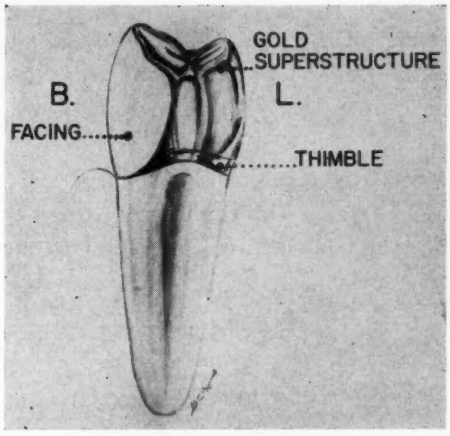

Fig. 5.—The completed telescopic crown.

occlusal records are made and a plaster impression of the involved structures is made with a hard plaster. The primary thimbles are removed with the impression.

A master cast of a low-fusing metal is poured without replacing the dies. In this manner, the primary thimbles can be replaced on the master cast in the correct relationship each time they are removed.

After the master cast is completed, the thimbles are rechecked with a surveyor for proper alignment because their positions are now more accurate than on the first cast. Any modification of them should be made at this time by grinding. The gold must not be overheated during this grinding, however, because the low-fusing metal beneath it may melt, contaminate the gold, and destroy the cast. Convexities in the thimbles are reduced, and concavities are corrected with the handpiece locked in the surveyor. This will assure optimum parallelism for insertion and frictional retention for the superstructure.

THE TELESCOPIC SUPERSTRUCTURE (CROWN)

The telescopic crowns, instead of being waxed on the thimbles, may be made of cold-cure acrylic resin, and the entire resin superstructure can be tried in the mouth (Fig. 3). Thus, all modifications in contour and occlusion are performed in the mouth. Space for acrylic resin facings is cut in the resin and retentive loops and grooves are formed in wax. The entire superstructure is cast as one unit.

Full gold crowns with buccal or labial acrylic resin veneers (Figs. 4 and 5) are most frequently used for the superstructure. However, the crowns may be made

of a gold shell which is entirely veneered with resin, except for the occlusal surfaces and the proximal contact areas (Fig. 6), if the minimum of gold is to be exposed.

The labial gingival margins of the superstructural components should extend into the gingival sulcus but should not penetrate into the underlying tissue (Fig. 7). The labial surface of the superstructural crowns should be thin to prevent overcontouring and to allow sufficient thickness for acrylic resin facings.

More detailed planning of the superstructure is necessary with an increase in the number of units. Although the superstructure may be cast as a unit, it is better to cast each abutment crown individually, especially when there are multiple abutments.

The individual crowns are seated on the thimbles and a plaster impression is made. A new master cast is made with the primary thimbles in place. The pontics are waxed and cast and the superstructure is soldered into one unit.

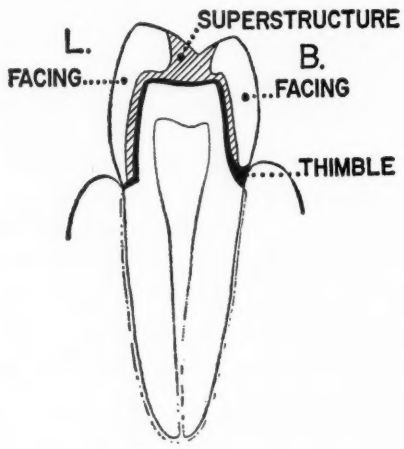

Fig. 6.—The crown may be almost entirely veneered to show less gold.

After the superstructure is completed in gold, it is tried in the mouth and the occlusion is adjusted. The facings are waxed on the gold framework for esthetic correctness, and the desired shade of acrylic resin is processed.

CEMENTATION

Finally, the primary thimbles are cemented with permanent cement as individual units, but not until the superstructure is completed. The holes on the lingual surfaces of the thimbles provide egress for excess cement. The excess cement inside the crown is removed before the cement sets. The superstructure is cemented later as one unit with zinc oxide and eugenol temporary cement.

The restoration may be inserted by fitting the primary thimbles extraorally into their respective telescopic crowns without cement. Then, the primary thimbles

are filled with zinc oxyphosphate permanent cement, and the entire assembly is seated with the superstructure in position.

A more conservative method consists of first inserting the primary thimbles within the superstructure and then seating the primary thimbles and superstructure without cement. The superstructure is removed and the primary thimbles are tapped into position on the individual teeth. Each primary thimble is then removed separately, filled with a thin film of cement, and recemented. The superstructure is seated in place as each thimble is cemented to ensure proper placement of the thimble as the cement hardens. After the thimbles are in position (Figs. 8 and 9), the superstructure is cemented with a zinc oxide and eugenol temporary cement (Figs. 10 and 11).

When the abutments are tipped, the primary thimble should be cemented to the tooth rather than inserted into the assembly. If the primary thimble was placed

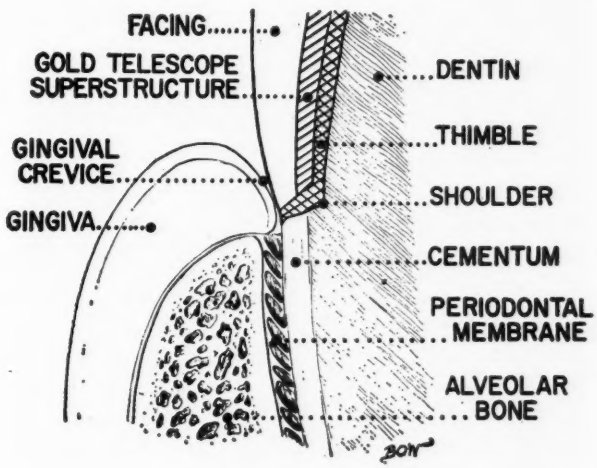

Fig. 7.—The margins of the crown should not impinge on the gingival tissues.

in the outer splint first, the entire assembly might not go into place. When the tooth is extremely malaligned, the shape of the primary crown is altered to permit the superstructure to be inserted without difficulty.

ADVANTAGES

For proper diagnosis, a restoration must be removed to check individual teeth for hyperemia of the pulp, abscesses, periodontitis, hypermobility, and other complications. With this technique, the pulp can be checked readily by perforating the primary (thimble) crown and testing the tooth with a pulp tester. The opening is repaired with gold foil without jeopardy to esthetics or mechanics.

Endodontic therapy can be undertaken by penetrating the primary crown. The use of a rubber dam is facilitated, since access to the involved tooth is unencumbered by the presence of other denture units. The thimble is easily repaired after

endodontic therapy. If a rather wide opening of the primary thimble is necessary for proper endodontic treatment, the opening can be repaired without disturbing the other primary thimbles or the superstructure.

When a nonterminal abutment tooth must be extracted, the superstructure is removed and the tooth extracted. The extraction site is permitted to heal, and then the superstructural crown is modified into a pontic by reshaping it and processing

Fig. 8.

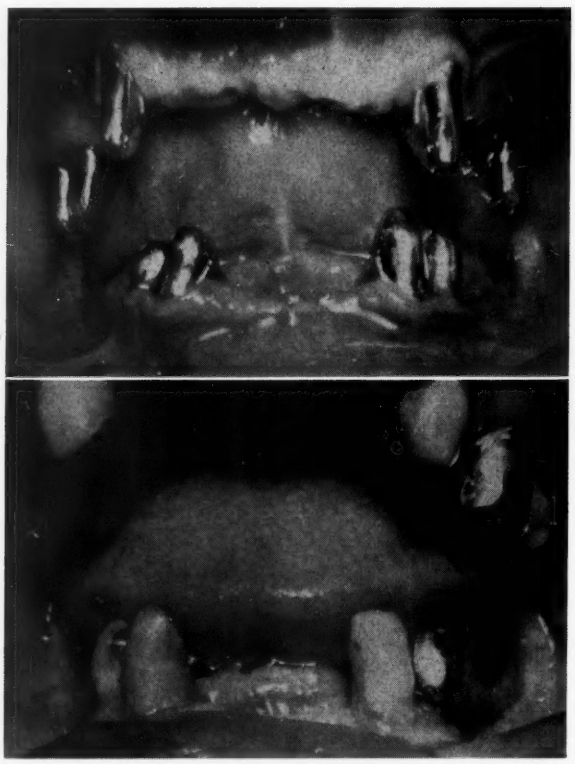

Fig. 9.

Fig. 8.—The thimbles are cemented in the mouth.
Fig. 9.—The mouth of the same patient as seen in Fig. 8 before reconstruction.

acrylic resin into it. As a precautionary measure, a master cast of the entire substructure of the mouth should be retained so that a temporary acrylic resin splint may be prepared if the superstructure requires repair. The master cast is made after the primary thimbles are cemented in place.

Another advantage becomes apparent when excessive gingival recession occurs some time after the restoration is placed in the mouth. This presents a hazard to esthetics and introduces the risk of root caries. The tooth is reprepared by extending the preparation to the new gingival line. A copper-band impression is made, and a die is constructed of a refractory investment. The superstructure is

Fig. 10.—The superstructure is cemented with a temporary cement.

filled with cold-cure resin and is placed in the mouth so that it covers the tooth preparation. The superstructure is removed after the resin has cured, the die is placed into the resin crown, and the margins of the crown are finished in wax. The corrected resin crown is invested, burned out, and cast, and the new thimble is cemented on the newly prepared tooth. Thus, the root surface exposed by recession is covered, and the proper position of the new thimble in the old superstructure is maintained.

PATIENT SELECTION

Patient selection in this technique is important for optimal results. Patients with short teeth present a problem in retention of the superstructure unless the interocclusal distance permits increase of the height of the abutments by lengthening of the primary thimbles. Patients with crowded mandibular anterior teeth also present a problem. The limited space does not permit the necessary bulk for the gold–acrylic resin combination that this technique requires.

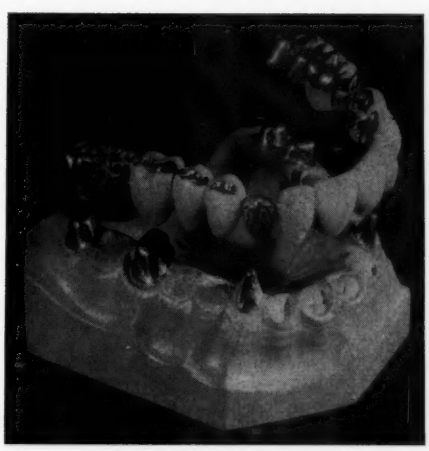

Fig. 11.—A sample restoration shows two variations of the finish of the occlusal surface.

SUMMARY

A technique has been described that utilizes a thimble substructure and telescopic superstructure for dental reconstruction. This technique represents a modification of the telescopic crown principle. The advantages of this technique are explained.

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PRODUCTION OF SILVER SURFACES ON DENTAL CASTS

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THE MAIN ADVANTAGES OF A METAL-COATED DIE are its hardness and its marginal detail despite considerable handling. These advantages are accentuated during the fitting of a cast-gold inlay, because deformation of the die will not occur and an inaccurate casting becomes immediately apparent. Inasmuch as a lubricant between the silver surface of the die and the wax pattern is unnecessary, another possible source of difficulty is eliminated.

Phillips and Schnell[1] concluded that metal-coated dies are less accurate than those produced from dental stone. Nevertheless, they indicated that plating of polysulfide rubber impressions produced casts of clinical acceptability. They used the Bureau of Standards' MOD type of die as a basis for comparison and observed a slight convexity of the pulpal floor of the die produced from it. In general, difficulty in removal of the plated cast from the polysulfide rubber impression was not encountered. However, the faithful reproduction of rough surfaces could cause it to be difficult to separate the cast or die from a rubber impression.

PLATING EQUIPMENT

Suitable commercial apparatus are available for simultaneously plating several rubber impressions. However, some difficulty has been experienced in adjusting the current density to appropriate values for a single-quadrant impression because of the low sensitivity of the electrical meter.

An inexpensive apparatus can be easily constructed from parts obtainable from any supplier of radio components. The basic features of the wiring circuit were suggested by Bliss[2] (Fig. 1). The total cost of the apparatus that I constructed was about $12.00. The apparatus is built into an aluminum chassis with plug-in leads for the anode and cathode connections (Fig. 2). A plastic dish of the sort used in domestic refrigerators contains the plating bath. The plastic cover of this dish is drilled to accommodate sockets, and alligator clamps are soldered in place on the underside of the cover to hold the anode metal and the object being plated.

EXPENDABLE MATERIALS

The plating solution consists of 15 ounces of silver cyanide dissolved in 1 quart of distilled water. The solution should be aged 24 hours before use.[3] The cyanides are extremely toxic, and possible contamination with acids must be avoided. The plating unit should be operated in a well-ventilated room.

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The silver content of the solution is maintained by dissolution of the anode. Therefore, the original volume of solution should not change except through evaporation of water. An appropriate mark on the tank should indicate the original volume, which can be preserved by addition of distilled water. Minor amounts of sludge that accumulate on the bottom of the tank must be removed by filtering the solution through paper. The surface of the anode should be approximately twice that of the object being plated.

A fine silver powder is required in addition to the piece of silver which serves as the anode. The powder establishes an electrical conducting surface on the nonconducting impression material.

PROCEDURE

If no contaminating substances are present, the impression is cleaned and rinsed with water and dried. If blood or saliva is present, the impression is washed with a mixture of 50 per cent denatured alcohol and 50 per cent hydrogen peroxide using a camel's hair inlay brush.[2] A commercial debubblizing solution also may be used.

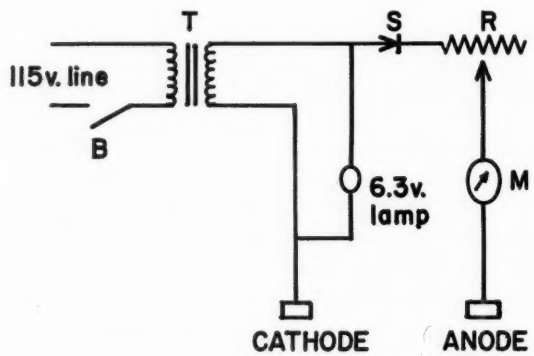

Fig. 1.—A wiring diagram for a simple plating apparatus. *T*, the transformer: 6.3 volts, 2 amp. (estimated cost, $3.00); *S*, the rectifier: 6-plate selenium (estimated cost, $1.50); *R*, the potentiometer: 100 ohms (estimated cost, $2.00); *M*, the milliammeter: zero to 100 Ma. (estimated cost, $2.00); *B*, the switch: off-on, 2-pole (estimated cost, $.60).

A masking substance is applied to the surfaces of the tray or band that are not to be plated. The adhesive used to coat the plastic trays before making a rubber-base impression is a suitable masking material. Next, the fine silver powder is dusted into the impression. All surfaces to be plated must be completely covered.

The impression is attached to the cathode. A piece of 28-gauge bare copper wire is wrapped around the impression to produce good electrical contact with the silver powder. The wire must not distort the impression. The fine wire is attached to a piece of stiff wire which is held in the alligator clamp (Fig. 3). Then, the impression is filled with solution from the tank by means of an eye dropper. If air bubbles are present, the solution is removed from the impression and replaced.

The impression is carefully placed into the solution and completely submerged. The concavities in the impression should face upward to prevent entrapment of air and to allow inspection during the plating process.

The plating unit is connected and the current adjusted by means of the potentiometer knob to 10 Ma. for a band impression or 60 Ma. for a tray impression.

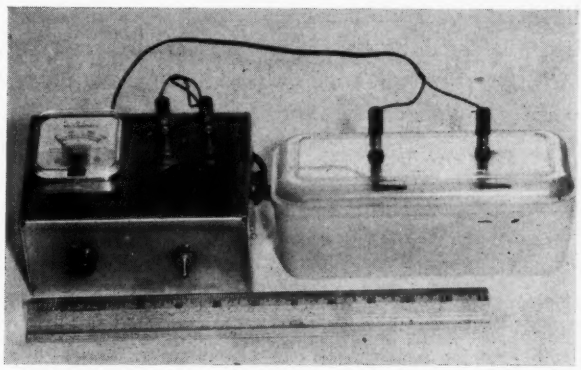

Fig. 2.—A silver plating apparatus and tank for the cyanide bath.

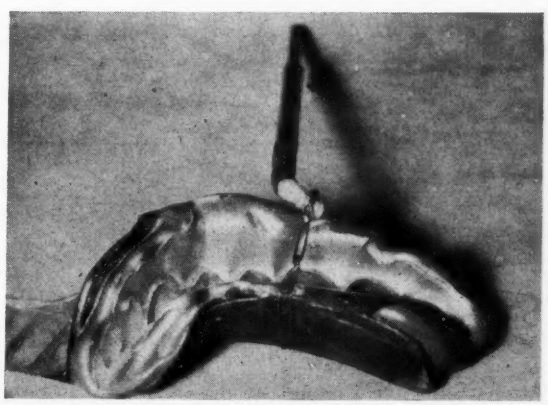

Fig. 3.—The impression is attached for plating. The portions of the impression to be plated have been dusted with silver powder.

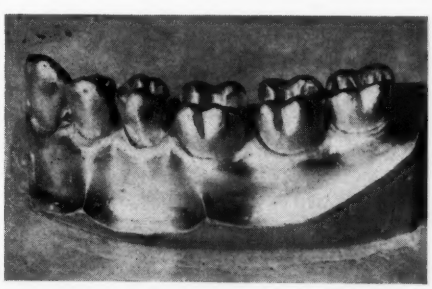

Fig. 4.—The silver-plated die is completed and ready for sectioning.

The flash coating is deposited within 1 or 2 minutes. If the current is too great, the solution will bubble and the silver deposit will have a granular appearance. After 1 hour, the impression is removed from the tank and inspected. Surfaces that have not received the flash coating are apparent and should be redusted with silver powder after the impression has dried.

The impression is replaced in the solution, and the current is raised to 50 Ma. for each band impression or to 100 Ma. for each tray impression. The plating should be continued overnight if a thick coating on the die is desired. If plated for 4 to 6 hours, the impression will have a silver thickness of about 0.004 inch. The silver coating, of course, does not alter the dimensions of the final cast.

Dowel pins are inserted in the usual manner, and the cast is poured in artificial stone. After the stone has set, the die is removed from the impression (Fig. 4) and sectioned.

SUMMARY

A simple procedure and an inexpensive apparatus for making silver-plated dental casts from rubber-base impressions has been described. The accuracy of such casts is clinically acceptable under most circumstances, and the hard, silver surface has qualities superior to those of artificial stone.

My appreciation is expressed to Dr. Duncan McConnell for technical and editorial guidance and to Dr. Donald W. Dickson for general guidance on operative techniques.

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ESTHETICS AND THE GINGIVAE IN FULL COVERAGE

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ESTHETIC APPEARANCE WITH FULL-COVERAGE RESTORATIONS is dependent on anatomic form, the materials used, and the maintenance of gingival health. All too often, extensive restorations are surrounded by enlarged, edematous, inflammatory gingivae. It is convenient to rationalize that the cause of gingival inflammation is calculus and/or poor tooth brushing. In reality, esthetic restorations and the maintenance of healthy gingivae start with the preparation of the tooth. A long-standing successful result depends upon many details associated with the handling of the materials and an understanding of the maintenance of the gingivae during the procedure itself. Without this initial basis, the beneficial results of diligent tissue maintenance are compromised.

This article emphasizes the dynamic relationship of the design and construction of full-coverage restorations with regard to esthetic appearance and gingival health.

RECONSTRUCTION DIAGNOSIS AND PERIODONTAL CONDITION

Pathologic periodontal conditions should be completely eliminated before final reconstructive procedures are instituted. Permanent multiple splinting is not a substitute for periodontal treatment. Splinting cannot eliminate periodontal pockets, granulomatous tissue, and unfavorable gingival contours. However, this does not exclude the need for temporary splinting as an adjunct to periodontal therapy.[1,2] The final prognosis and treatment plan are made after a thorough analysis of the occlusion and the forces involved.[3,4]

If the periodontal treatment is not carried out, the projection of the restorations into involved lesions will act as an added irritant, which causes ultimate failure.

MARGIN PLACEMENT

Margins of preparations are often placed well below the gingivae to avoid recurrent caries. This relationship of the crowns to the gingivae encourages periodontal disease. The usual tissue response is recession, or pocket formation. Gingival recession produces a marginal relationship between the gingivae and the restoration which does not afford any more protection against caries than if the finish lines were initially placed up to or only slightly below the free margin of the gingivae. Indeed, since a dynamic situation is created, the gingivae may recede well beyond the margin of the restoration. Pocket formation, on the other hand, requires periodontal therapy for reduction.

The only answer to the caries problem is exact marginal fit with proper maintenance. The margins of all posterior restorations should be placed up to and only slightly below the free margin of the gingivae (less than 1.0 mm.). Thus, the restoration is placed into the gingival sulcus without damage to the periodontal fibers. Deeper placement usually causes permanent damage to some of the gingival and transceptal periodontal fibers, with the resultant apical migration of the epithelial attachment. This apical migration usually results in permanent gingival recession, or worse, the formation of a periodontal pocket followed by alveolar resorption.

GINGIVAL PAPILLAE

The health of the gingival papillae is often more difficult to maintain than the health of the buccal or lingual tissue. Tooth brushing and food stimulation usually provide more stimulation to the buccal and lingual gingivae than the interproximal papillae. The blood drainage from the buccal and lingual gingivae is mainly through the soft tissue overlying the bone.[5] Any stimulation of these tissues helps maintain gingival health. The gingival papilla, on the other hand, is relatively

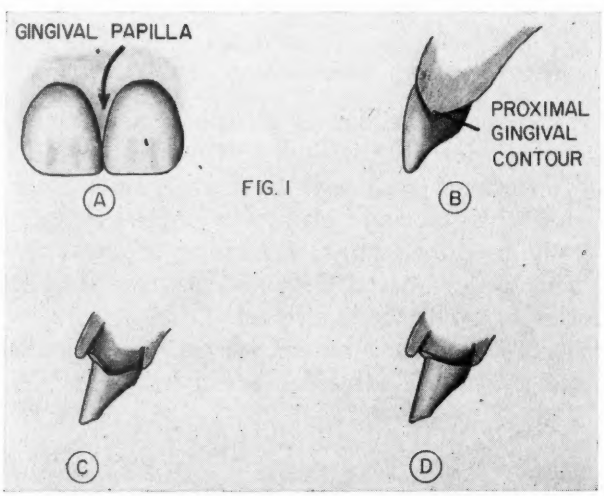

Fig. 1.—*A*, The interproximal triangular space must not be violated. *B*, The gingival papilla is located occlusally to the labial and lingual gingival margins. *C*, The proximal finish line approximates the contour of the gingival papilla. *D*, The straight "slice" from the labial to the lingual surface at the gingival margin is contraindicated.

protected from food stimulation and less diligent tooth brushing. The blood drainage of the papilla is mainly through the interceptal bone.[5] Usually the gingival papilla must be stimulated by excellent tooth-brushing methods supplemented with interproximal stimulation itself.[6]

INTERPROXIMAL SPACE

In order to maintain the health of the gingival papilla, the interproximal triangular space occupied by the papilla must not be violated (Fig. 1, *A*). This triangular space is often violated when the clinical crowns are short and the interproximal surfaces of the teeth are close together. A shoulder placed on the proximal surfaces of teeth creates space for firm castings and an acceptable solder joint without obliterating this triangular space.

Finish Line Contour.—The height of contour of the ginigival papilla, when it fills the interproximal space, is located occlusally to the labial and lingual gingival margins (Fig. 1, *B*). The finish line on the proximal surface should approximate this contour (Fig. 1, *C*) rather than "slice" through in a straight line from the labial to the lingual finish line (Fig. 1, *D*). When this incorrect proximal marginal outline is followed, gingival fibers are permanently cut, and the first step toward periodontal disease has been taken by the dentist.

Shoulder Preparations.—When veneer crowns are used, the labial shoulder must be carried into the interproximal embrasure. When no shoulder is provided on

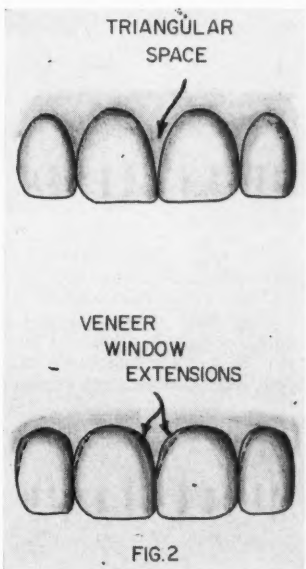

Fig. 2.—When no interproximal shoulder is provided, the added bulk of the veneer crown encroaches on the triangular space, contributing to periodontal disease and producing an unesthetic restoration.

the proximal surface, the gold framework must be extended into the interproximal space to make room for acrylic resin (or porcelain). This added bulk outside the normal contour of the tooth encroaches on the triangular space (Fig. 2). Thus, the second step toward a pathologic periodontal condition has been taken.

The added bulk at the gingivae margin produces an unesthetic, abnormally shaped crown (Fig. 2). One of the reasons for the esthetic appearance of unit-built fixed partial dentures is that complete labial and interproximal shoulders are used, and this allows space for proper interproximal contouring.

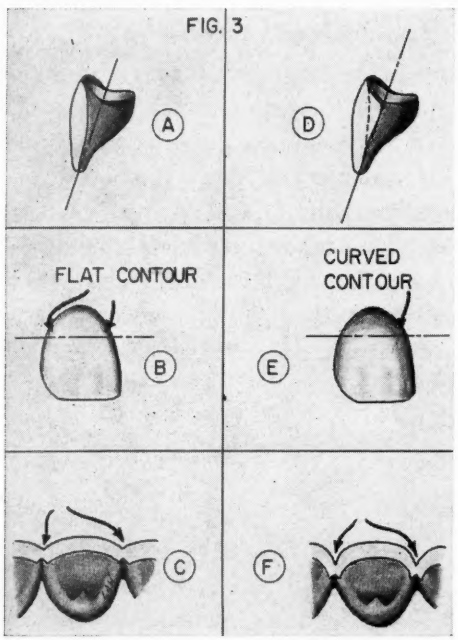

Fig. 3.—*A*, The veneer is waxed in a graceful arc curving labially from the incisal edge to the gingival margin. *B*, This design produces a flat veneer which lacks a three-dimensional appearance in its gingival area. *C*, The cross section of *B* taken at the dotted line indicates that the veneer window is flat and lacks a three-dimensional, natural effect. *D*, The labial shoulder of the preparation is carried into the embrasure. *E*, Then the finished veneer can be carried more interproximally to produce a natural, three-dimensional effect. *F*, The cross section of *E* at the dotted line indicates a natural, three-dimensional effect without added bulk.

TEMPORARY CROWNS

Temporary crowns not only protect the teeth but have a vital relationship to periodontal function as well. The acrylic resin temporary crown splint prevents drifting and occlusal trauma of mobile teeth during reconstruction. The contours of the temporary crowns prevent food impaction on the gingivae.

Whenever the temporary resin restorations are cemented, all traces of temporary cement and/or impression materials must be removed from the gingival crevice to prevent periodontal injury. This precaution usually ensures good gingival tone and color while the fixed partial denture is being constructed. Well-worn anterior curettes are excellent for this purpose since very little soft tissue curettage takes place.

GOLD VENEER CROWNS

Usually, veneer crowns are waxed with the proximal outline of the window extending in a graceful arc curving *labially* from the midline of the tooth at the incisal edge to the gingival margin (Fig. 3, *A*). This design produces a flat veneer which lacks a three-dimensional effect at the gingival surface (Fig. 3, *B* and *C*); the temporary resin crowns often look better anatomically than the finished product.

The labial shoulder must be carried into the interproximal embrasure to remedy this situation. Then the window outline can be extended along the midline of the tooth to the gingival margin without curving labially (Fig. 3, *D*). The finished veneer can be carried interproximally, which produces a natural, three-dimensional effect without added bulk. This effect is created by the gentle labial and interproximal curvature which is found in the natural teeth (Fig. 3, *E* and *F*). With the proper preparation, this procedure does not result in impingement on the triangular interproximal space, but preserves that space for the papillae.

The retention for the acrylic resin facing is not affected, because the "window" usually slopes outward in this area. The solder joint, which is located occlusally, is not reduced since the change in window design is made only on the gingival third of the crown.

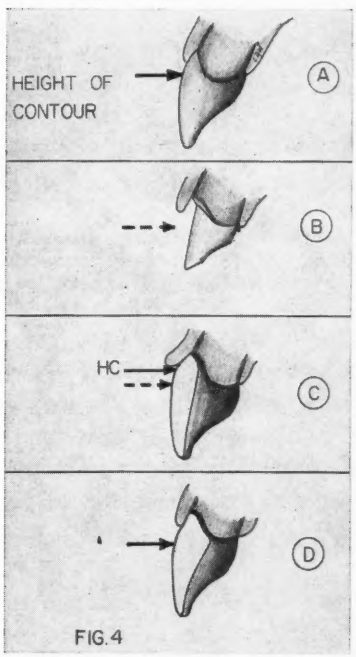

Fig. 4.—*A*, The veneer facing should have an anatomic form that closely resembles that of the natural tooth. The height of contour is located at the gingival third of the crown. *B*, Usually, shoulders are placed below the gingivae and a bevel is made. An arrow indicates the original level of the height of contour at the gingival third of the tooth. *C*, A faulty wax-up places the height of contour *(HC)* in relation to the gold crown height rather than the original level (arrow). This causes gingival impingement and an unesthetic anatomic contour. *D*, A properly contoured facing produces a height of contour at the original level (arrow), causes no gingival impingement, and produces an esthetic restoration.

VENEER CONTOURING

Veneer facings should have an anatomic form closely resembling the original tooth (unless changes are desired). The height of contour is located on the gingival third of the tooth (Fig. 4, *A*). Usually, shoulders are placed below the gingivae and a bevel is made (Fig. 4, *B*). The crown is often waxed by a technician in the laboratory who has no idea of the position of the gingivae or the original anatomic arrangement of the teeth. Consequently, he places the height of contour in relation to the crown dimensions, which results in an overly large, unesthetic crown that impinges on the gingivae (Fig. 4, *C*).

The laboratory technician can be instructed to place the gingival height of contour at a more incisal level. Study casts can serve as a guide to him. The correct anatomic design of the veneer places the height of contour at the original

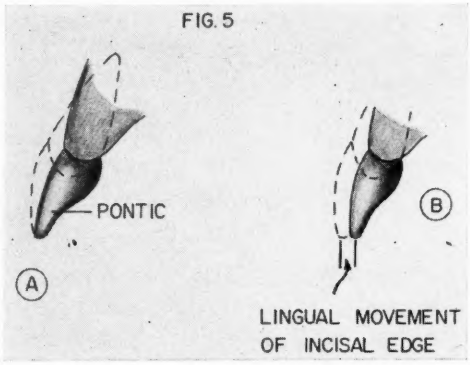

Fig. 5.—*A*, The labial gingival edge of the pontic is usually lingual to the margins of the adjacent abutments (dotted outline). *B*, The unesthetic appearance is avoided by placing the incisal edge of the pontic slightly lingual to the adjacent tooth (dotted outline) when the occlusion permits.

level, which affords less bulk to impinge on the gingivae (Fig. 4, *D*). The contour of the facing wax-up should be checked in the mouth before it is flasked and processed. Unless the preparations and gold castings are made correctly, the improvement of the wax facing in the mouth is limited. The veneer window can be narrowed gingivally and the wax-up changed accordingly to improve the appearance and gingival relationship.

ANTERIOR PONTIC DESIGN

The gingival edge of the labial surface of the pontic is usually lingual to the same margin on adjacent abutments because of the atrophy of the residual alveolar ridge that occurs after extraction. If the incisal edge of the gold pontic is placed in line with adjacent abutments, the face of the pontic will have an exaggerated lingual tilt (Fig. 5, *A*). This unesthetic appearance can be avoided, occlusion permitting, by placing the incisal edge of the pontic slightly lingual to the adjacent teeth (Fig. 5, *B*). The lingual orientation also adds to the character of the restora-

tion. In addition, the veneer facings can be waxed to show overlapping or rotation. These esthetic touches, which are commonplace in complete denture construction, are often lacking in fixed partial denture construction.

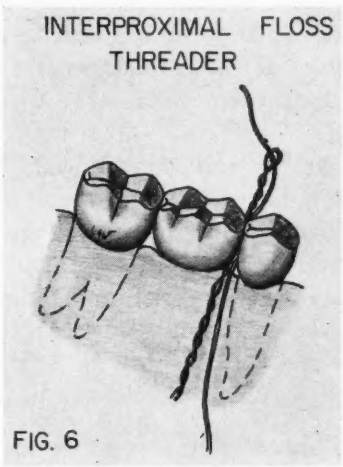

Fig. 6.—A floss threader is made of 0.010-inch steel wire and is used to guide the floss through the interproximal space for cleansing the pontic.

FINAL PROCESSING

Color.—When acrylic resin veneers are used, attention to a few details can make the result esthetic. One part of dark gray to twenty parts of the correct shade usually reduces the artificial yellow look often associated with acrylic resin veneers. One-half to one part of opaque white is often added, depending on the degree of translucency or opacity of the natural teeth. With fast-setting acrylic resin opacifiers, the thickness of the veneers need not be excessive. Incisal colors should be blended by slicing the body color away in an inclined cut starting at about the midline of the tooth.

Processing.—The anatomic form and texture of the surface should be carved into the wax. Small circles and wavy lines are carved into the wax to simulate the natural surface texture. After processing the veneer, the excess resin (flask) is trimmed without touching the veneer surface itself because the finish cannot be rematched for esthetics. Once the veneer surfaces are carved and repolished, some of the natural translucency and lifelike character is lost. When necessary, very thin steel disks are used to modify the labial interproximal surface of the veneers to accentuate the individual three-dimensional effect. This is *not* followed by polishing on the labial face.

CEMENTATION

Final cementation of the restoration is followed by periodontal curettage to remove all foreign matter from the gingival sulcus. Roentgenograms often reveal particles of cement in undetected places.

POSTOPERATIVE PERIODONTAL CARE

The occlusion should be checked carefully at frequent intervals for deflective occlusal contacts. Fixed partial dentures distribute the forces of occlusion differently than individual teeth,[3,4] and these new forces can result in minute shifting of the whole restoration. Because of the lever arm distances, a small movement of the roots of the teeth is magnified at the occlusal surface and can produce occlusal trauma. With full-mouth construction, particularly, the patient's chewing pattern can change.

The patient's tooth-brushing procedure should be reviewed and instructions given on pontic cleansing. Sometimes it is difficult for the patient to thread the dental floss through the interproximal space. As an aid, a "floss threader" can be easily made of 0.010-inch steel wire which is bent double and twisted so it has a small loop at the end. Dental floss is threaded through the loop. The loop is pushed through the interproximal space next to the pontic (Fig. 6). The dental floss is then grasped with the fingers as the loop is removed. The pontic can be cleansed so easily in this manner that the patient is encouraged to maintain the restoration in a hygienic condition.

SUMMARY

Some of the important factors in the design and construction of full-coverage restorations have been described in relation to esthetics and gingival health. A basic procedure for full-coverage veneer crowns has been suggested which affords the best possible results within the limitations of the materials commonly used.

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TEMPOROMANDIBULAR JOINT DYSFUNCTION

TEMPOROMANDIBULAR JOINT PAIN REFERRED FROM MUSCLES OF THE HEAD AND NECK

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TEMPOROMANDIBULAR JOINT DYSFUNCTIONS comprise a large proportion of the complaints presented to dentists. Surveys place the incidence at about 20 per cent.[1] In many of these patients,[2,3] examination reveals no organic disease of the mandibular articulation itself, of the teeth or gums, or of the bones of the head and neck and no disease of the circulation or the peripheral or central nervous system. Too often, the condition is classed as psychosomatic. In this event, the skeletal muscles may not even be considered as potential sources of pain and imbalance at the temporomandibular joint.

The importance of muscular dysfunction in temporomandibular joint disorders should be self-evident because, in the first place, the security of this articulation depends not so much on its ligaments and bony configuration as on the powerful antigravity muscles of mastication that keep the condyles of the mandible in place and because, secondly, the complex normal movements of the joint require an efficient and relaxed musculature.

This article will deal with pain perceived in the mandibular articulation but referred to it from the muscles of mastication and from certain muscles of the neck. Clinical pain syndromes of the masticatory muscles have been highlighted by a number of reports in the medical and dental literature[1,4-17] but still lack the "high index of suspicion" that is a prerequisite for diagnosis.

PATHOPHYSIOLOGIC COURSE

In these nonarticular or periarticular entities *(stress disorders of the skeletal muscles),* the pathophysiologic course of events may be outlined as follows.

Investigations of myofascial pain cycles and methods for their interruption have been supported in part by the Josiah Macy, Jr. Foundation, the National Heart Institute of the National Institutes of Health (#493), U. S. Public Health Service, and the Joseph P. Kennedy Jr. Foundation.

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When the muscles are subjected to noxious stimulation of various sorts (mechanical, emotional, infectious, metabolic, or nutritional, or more likely to a combination of several of these stresses), they react in *one* way—they develop spasm and shorten. Muscles in spasm lose the capacity for voluntary relaxation and also exhibit an overactive stretch reflex, or resistance to passive lengthening.

Electromyographic recordings from the masticatory muscles in patients with temporomandibular joint problems due to malocclusion have shown[18] a low-grade sustained electrical discharge characteristic of muscle spasm; often the normal state of electrical rest could be restored by correction of the occlusal disharmony.

Involuntary shortening of one or more of the masticatory muscles may cause an eccentric position of the mandibular condyle, disorientation of jaw movements, and restricted opening of the mouth. Also, clicking and grating sounds can be created by abnormal tensions in the muscles that cross the temporomandibular joint and bind its articular surfaces together. Pain is the outstanding complaint. When a muscle, or part of a muscle, shortens beyond a certain physiologic limit, pain may be of terrific intensity. The pain of skeletal muscle spasm is often as intense as the labor pains of the strongly contracting uterus, but becomes unendurable when it has no letup.

We have observed[4,5,19-25] that whenever pain associated with skeletal muscle spasm is so severe as to present a problem of clinical consequence, it is almost always referred a distance from the muscle that is its source. The projected or referred pain depends on a small zone of hypersensitivity, known as a trigger area, located within a muscle in spasm or in fascia. At this spot, there is a lowered pain threshold to stimulation by pressure.[23] Deep pressure on the trigger area or touching it with the point of a needle reproduces the spontaneous pain at a distance, and infiltrating it locally with procaine eliminates the related reference of pain.

At the outset, shortening of muscles under stress represents homeostatic protection against injury. The protective splinting, however, tends to gain momentum so that increasing numbers of related muscle groups develop spasm, and the pathways of the spasm-pain-spasm chain reaction become extensively facilitated. As a result, painful spasm and its concomitants outlast the precipitating event, and the mere passage of time does not bring about recovery. "Injury initiates a deteriorative biochemical cycle,"[26] a concept that has been given a firm experimental basis by Selye.[27]

Painful shortening of skeletal muscle may remain a pathophysiologic process for long periods, as shown by its ready reversibility. In a matter of minutes, local procedures directed at extinguishing trigger areas may abolish the hyperirritable stretch reflex and re-establish normal muscle length and function, even though movement has been painful and limited for months or years. Only a pathophysiologic disorder, analogous perhaps to the discharging focus of paroxysmal cardiac arrhythmia, could be immediately and permanently terminated by such procedures as ethyl chloride spray and local procaine infiltration, which have only transitory pharmacologic effects. Furthermore, biopsy of trigger areas has proved unrewarding[5]; pathologically, nothing distinguishes these trigger areas.

If muscle spasm is allowed to cause marked limitation of motion long enough, fibrosis of periarticular structures gradually ensues, and contracture rather than

spasm becomes responsible for joint restriction. In this stage, pain diminishes and local measures for interrupting myofascial trigger mechanisms become less and less effective. In some patients, the organized connective tissue change apparently develops quite soon after the precipitating stress, whereas in others it remains minimal for indefinite periods. *Immobilization, either by an external appliance or by conscious or subconscious inhibition of voluntary movement, is a major factor in the rapid progression of painful muscle spasm to painless adhesive periarthritis.*

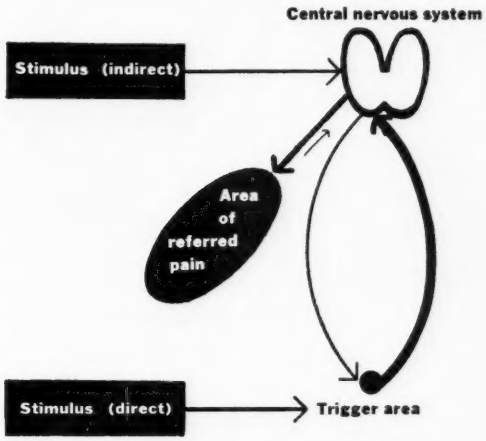


Fig. 1.—Theoretic pathways of activating stimuli and secondary linkage of trigger area with its reference zone. (From Pfizer Spectrum: Trigger Areas, J.A.M.A. 152:26 Adv., 1953.)

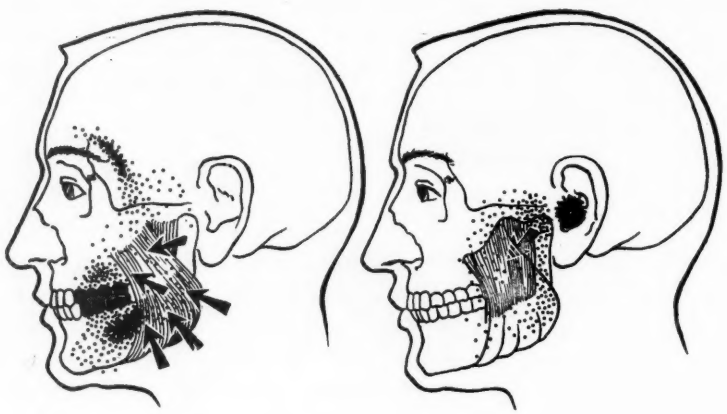
REFERRED PAIN AND ITS CONCOMITANTS

Each skeletal muscle, and even each part of a muscle, has a specific pattern of referred pain; that is, a trigger area at a particular site gives rise to essentially the same distribution of referred pain in one person as another. The referred pain patterns of the muscles do not necessarily follow a simple neurosegmental distribution, but their constancy implies fixed anatomic pathways which link the trigger area with its reference zone. Furthermore, the relationship of the trigger area to its reference zone is the same whatever the nature of the activating stress (Fig. 1).[28] Whether noxious stimuli are applied directly to the muscle, as in trauma, overwork, or chilling, or whether they reach the muscle indirectly from the viscera or brain via the central nervous system, the same pathway is facilitated between the trigger area and the region interpreted as painful.

We have mapped patterns of referred pain in patients with myofascial pain syndromes, chiefly by the method of needling the abnormal foci, or trigger areas, that have appeared spontaneously within the muscle mass. When a needle is similarly inserted into normal muscle, which is not tender and not painful, no pain reference is produced. However, the injection of hypertonic salt solution into *normal* muscle evokes transient referred pain. We have employed this procedure to map the distribution of referred myofascial pain in some instances.[5] Referred pain

patterns are similar in both methods. The latter method, however, yields no information as to where in the skeletal musculature trigger areas commonly develop as the result of the varied stresses of living.

Masseter Muscle.—The composite pain reference pattern of the masseter muscle is shown in Fig. 2. Trigger areas in its *superficial* layer refer pain mainly to the



A. *B.*

Fig. 2.*—Pain reference patterns of the masseter muscle: *A*, Superficial layer. *B*, Deep layer. Trigger areas are indicated by arrows, and their pain reference zones by the stippled and black regions.

jaws, molar teeth, and gums. From the anterior border and upper part of this division of the muscle, pain is referred to the upper molar teeth, whereas from the lower part it appears in the lower molars. From trigger areas at the extreme angle of the mandible, pain travels upward in an arc across the temple and around the outer end of the eyebrow. Trigger areas in the shorter *deep* layer refer pain mainly to the temporomandibular joint and deep into the ear.

Kellgren[29] produced referred pain by injection of hypertonic saline into one site in the masseter muscle, where it lies over the angle of the mandible; pain was felt almost entirely within the mouth in the upper jaw like a "toothache," with some pain perceived in the temporomandibular joint and external auditory meatus.

Temporalis Muscle.—The temporalis muscle has the capacity to refer pain to the side of the head and to any or all of the upper teeth, depending on which spokes of the fan-shaped muscle harbor trigger areas (Fig. 3). From the anterior section of the muscle, pain is referred forward above the supraorbital ridge and downward to the upper incisor teeth. From the most posterior section of the temporalis muscle, pain is referred to the upper molar teeth and to the occiput. When trigger areas are present in the intermediate parts of the muscle, pain is perceived in the intervening teeth, in the temple, and less often, but occasionally intensely,

*This and the subsequent illustrations were prepared by Shirley Baty, Memorial Center for Cancer and Allied Diseases, New York City.

Fig. 3.

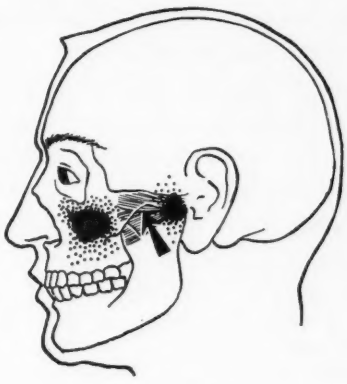


Fig. 4.

Fig. 3.—Composite pain reference pattern of the temporalis muscle. Trigger areas are indicated by arrows, and their reference zones by the stippled and black regions.
Fig. 4.—Composite pain reference pattern of the external pterygoid muscle.

in the temporomandibular joint. The deepest layers of the temporalis, like the masseter muscle, refer pain to this articulation.

External Pterygoid Muscle.—The composite referred pain pattern of the external pterygoid muscle is shown in Fig. 4. Owing to its relative inaccessibility beneath the zygomatic arch, the patterns of the two divisions of this muscle have not been clearly separated. Considered as a whole, it gives rise to pain referred deep within the temporomandibular and maxillary regions. Pain reference to the teeth from trigger areas in the external pterygoid muscle has not been observed.

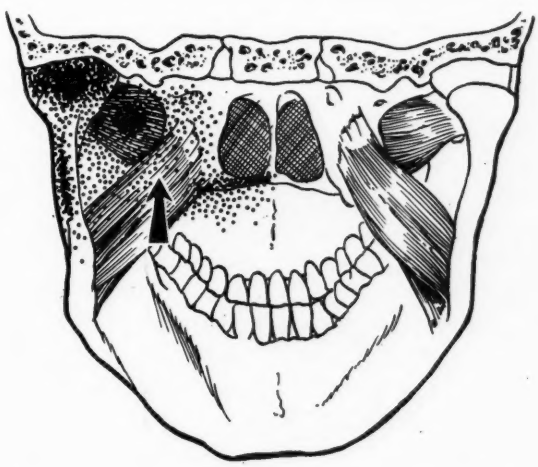


Fig. 5.—Composite pain reference pattern of the internal pterygoid muscle. A partial coronal section is shown with a view of the external and internal pterygoid muscles from the back of the mouth. Trigger areas at the arrow in the internal pterygoid muscle refer pain to the stippled regions. (Based on drawing by Netter, F.: Anatomy of the Mouth, Clin. Symp. 10:76, 1958.)

In our exeprience, this muscle is the chief myofascial source of referred pain felt in the temporomandibular joint.

Internal Pterygoid Muscle.—Pain reference zones of the internal pterygoid muscle include, mainly, structures within the mouth, the tongue, and hard palate posteriorly and within the temporomandibular joint itself (Fig. 5). Like the external pterygoid, this muscle has not been found to refer pain to the teeth.

Concomitants of Pain Reference From Masticatory Muscles.—

Case report: Let us take an illustrative case. Fig. 6 depicts the specific pain reference from three trigger areas in the temporalis muscle in a 44-year-old man who was seen in 1945 because of recurrent left facial neuralgia characterized by intense pain around the eye, tearing of the eye, toothache, excessive salivation, and moderately restricted opening movement of the mandible. All of the left upper teeth ached and were extremely sensitive to biting pressure. The onset of neuralgia was associated with exposure of the face to cold. The patient had discovered that pressure on the temporalis muscle accentuated tooth pain. No teeth were missing and no pathologic dental condition was found.

When a needle was inserted into the trigger area at site *1* of Fig. 6, intense pain was felt over the eye and mild pain in the upper incisors on the same side, with lacrimation of the left eye; at site *2,* pain was referred to the upper lateral incisor and canine teeth and was associated with intense salivation and slight lacrimation; at site *3,* pain was felt diffusely in the four posterior upper teeth without salivation or lacrimation. As soon as these trigger areas had been infiltrated with procaine, the pain was completely relieved, the teeth were no longer sensitive to pressure, and the maximum vertical aperture between the incisors with the mouth open had increased.

At another time, trigger areas in the deep layer of the masseter muscle posteriorly were found to mediate tinnitus and "stuffiness" of the adjacent ear; procaine infiltration of these abnormal foci promptly terminated these complaints.

During a follow-up period of 14 years, there has been no recurrence of symptoms referable to the muscles of mastication, although the patient has had multiple attacks of painful muscle spasm in other regions of the body, usually due to overuse.

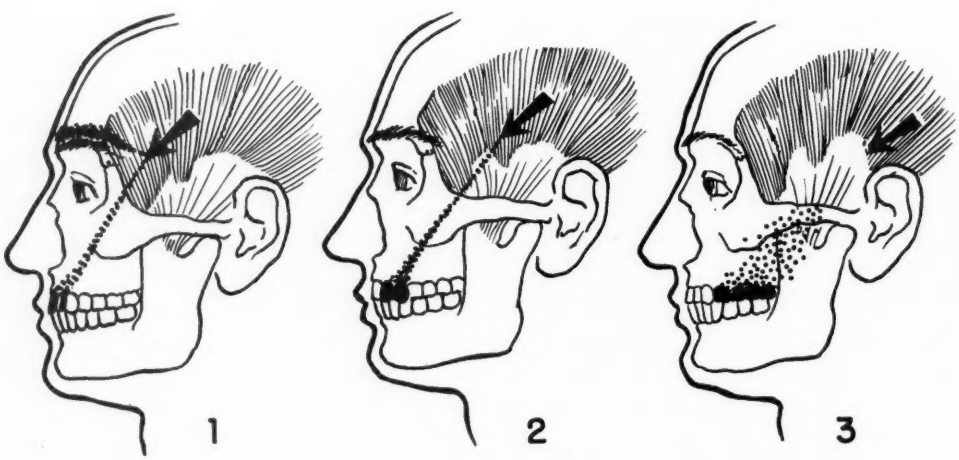


Fig. 6.—Specific trigger areas at three sites in the temporalis muscle, as observed in a case of facial neuralgia. Trigger areas were located at arrows, and pain was referred to the black and stippled zones.

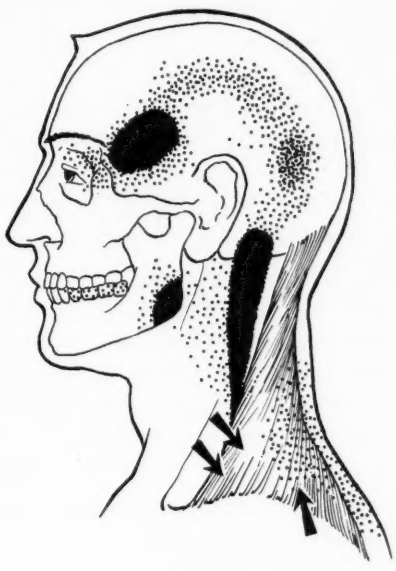


Fig. 7.

Fig. 8.

Fig. 7.—Composite pain reference pattern of the trapezius muscle, suprascapular region. Trigger areas are indicated by arrows, and pain reference zones by the stippled and black regions.

Fig. 8.—Composite pain reference patterns of the clavicular and sternal divisions of the sternomastoid. The sternal division refers pain mainly to the cheek, eyebrow, pharynx, tongue, chin, throat, and sternum. The clavicular division refers pain mainly to the forehead bilaterally, to the posterior auricular region and deep in the ear, and infrequently to the teeth. Trigger areas are indicated by arrows, and pain reference zones by the stippled and black regions.

In this patient, transient salivation and unilateral lacrimation were induced by stimulation (needling) of trigger areas. Nonpainful, localized, autonomic concomitants are not infrequently observed in association with extremely hypersensitive trigger areas.[5,23,30]

This case also brings out the fact that myofascial trigger areas give rise not only to referred pain but also to *referred deep tenderness.* Deep structures in pain reference zones become sensitive to ordinary pressure, and often to heat and cold. This referred hypersensitivity may persist during interludes when spontaneous pain is absent and the trigger mechanism is dormant. At this time, insertion of a needle into a latent trigger area evokes the predictable reference of pain, and its infiltration with procaine abolishes deep tenderness in its pain reference zones.

Since the teeth and gums serve as reference zones for trigger areas at many sites in the masseter and temporalis muscles, a pathophysiologic state of referred deep tenderness offers an explanation for the occasional unfortunate extraction of a painful and sensitive, but healthy, tooth.

Neck Muscles.—Two of the neck muscles, the trapezius and sternomastoid, have a tendency to develop stress disorders and exhibit referred pain patterns that overlap the patterns of the masticatory muscles. The accents of pain in the composite patterns are, however, different.

Trigger areas in the suprascapular portion of the trapezius muscle (Fig. 7) refer pain to the angle of the jaw, the posterolateral aspect of the neck and mastoid process, the temple, and the back of the orbit, with mild echoes of pain in the lower molar teeth and the occiput. Spasm of this muscle causes "stiff neck," with limitation of motion on looking to the contralateral side[31] and negligible restriction of mandibular movement.

In the case of the sternomastoid muscle,[4,5,23,24,30] the accents of referred pain (Fig. 8) are the forehead, supraorbital ridge and inner angle of the eye, middle ear and posterior auricular region, point of the chin, and pharynx, with diffuse pain in the cheek and infrequently in the molar teeth. The referred pain to the forehead often crosses to the opposite frontal region. A crossed pain reference to the forehead can usually be evoked by sustained compression of the clavicular division as it is encircled by the fingers and lifted off the underlying structures of the neck. When trigger areas are present in the inferior end of the sternal division of this muscle, pain is also referred downward onto the sternum.

When present, referred sternal pain is an important distinguishing feature since the distribution of pain referred from the muscles of mastication does not extend to the chest. Spasm of neither the masticatory nor the sternomastoid muscle causes any gross limitation of neck motion; spasm of the sternomastoid muscle does not cause serious disturbance of movement of the mandible.

Nonpainful concomitants of trigger areas in the sternomastoid muscle include: from the sternal division, blurred vision, homolateral lid lag, lacrimation, and coryza; from the clavicular division, homolateral sweating of the forehead, postural dizziness, and imbalance.[23-25]

The frequent association of trigger mechanisms in the sternomastoid and trapezius muscles (innervated largely by cranial nerve IX) with stress disorders of the masticatory muscles (innervated by the trigeminal nerve) is not surprising in view of the experimental studies of Green, De Groot, and Sutin.[32] They found that in decerebrate and decerebellate cats stimulation of any division of the trigeminal nerve induced efferent volleys in cranial nerves VII, X, XI, and XII; the sternomastoid and trapezius muscles contracted with stimuli of very low intensity from the nasal cavity.

Other Sources of Referred Pain.—It would be wrong to leave the impression that the voluntary muscles are the only skeletal structures capable of referring pain to the teeth. McAuliffe, Goodell, and Wolff[33] stimulated regions of the nasal and paranasal cavities and evoked direct pain in the teeth with secondary pain in the back of the head and neck after longer periods of noxious stimulation.

Noxious stimuli from the teeth themselves, if sufficiently prolonged, may give rise to headache and neck pain.[34-36]

CLINICAL FEATURES

Mode of Onset.—Stress disorders of the masticatory muscles with referred pain to the temporomandibular joint have several modes of onset. *Sudden* onset of pain and trismus are usually characterized by some traumatic episode, such as

too forcible contraction in biting on a hard object, overstretching of the jaw muscles, or a difficult tooth extraction, especially of an impacted third molar.

Gradual onset may be characterized first by the appearance of abnormal sounds in the joint and subsequently by pain and limited jaw motion, or vice versa. The major precipitating factor may be postural strain of the muscles due to occlusal imbalance or asymmetry of the face. The attack of painful muscle spasm may be associated also with an oral focus of infection, a respiratory infection, or acute emotional stress. Care must be taken to rule out organic disease such as local tumor growth and arthritis of the temporomandibular joint. Occasionally, a fulminating attack of facial neuralgia caused by gross trauma or overwork (microtrauma) of the sternomastoid and trapezius muscles precedes the gradual development of spasm in the masticatory muscles.

Even when the onset is abrupt and trauma is obvious, there is usually an antecedent period of gradual shortening of one or more of the masticatory muscles of which neither the patient nor the dentist is aware. Thus, the apparent precipitating cause is merely one event in a series of events.

Failure to recognize an *incipient* stress disorder of the muscles of mastication derives first from the fact that a person cannot tell by proprioception how wide the jaws open. Whenever a maximum effort is made to open the mouth, it feels wide open even though the aperture is limited by the increased stretch reflex of muscle spasm. Thus, the patient makes no complaint until the restriction is so extreme that he cannot bite into a sandwich. In order to detect moderate limitation of the vertical opening, the patient must either look in a mirror or gauge the extent of the opening by introducing his fingers into the aperture.

The second obstacle to early diagnosis is the current lack of standard measurements of the normal range of vertical motion at the temporomandibular joint. Physicians and dentists have been misled into accepting a limited opening as normal; an aperture of 3.0 cm. is often regarded as adequate.

Normal Jaw Aperture.—Some years ago, in collaboration with Dr. Nolton H. Bigelow, we measured the maximum vertical aperture between the incisor teeth on voluntary effort in 150 young adults (medical students and student nurses) who had no jaw muscle spasm according to history or examination. The values obtained were plotted against body height (Fig. 9). A rough correlation is evident, especially when a similar correlation for a group of children is included in the graph. For the 69 men with an average age of 21.7 years, the average vertical opening was 5.9 cm. (range 5.0 to 7.3 cm.), and for the 81 women with an average age of 19.6 years, it was 5.3 cm. (range 4.5 to 6.5 cm.). We conclude that the *normal jaw aperture at the incisive region for men of average height is not less than 5.0 cm., and similarly for women, not less than 4.5 cm.*

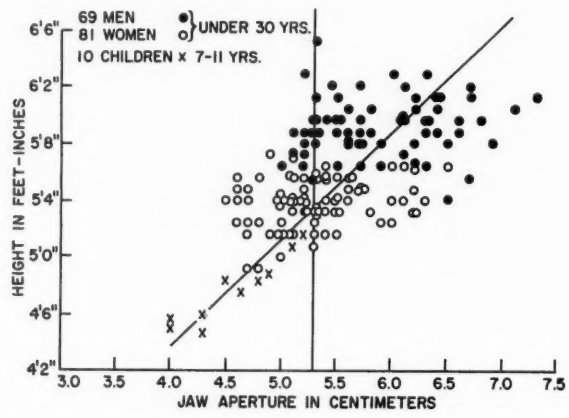
In older groups of men and women (average age 45.1 years), who were similarly without evidences of jaw muscle spasm, values for the maximum vertical openings were essentially the same as for the groups of 20-year-old individuals.

Our data agree closely with Dorrance's recommendation[37] that to check the normal jaw aperture, the knuckles at the proximal phalangeal joints of the

second, third, and fourth digits be inserted in a tier between the incisor teeth. We found that those people with a normal jaw aperture by direct measurement could meet this "rule of knuckles" criterion.

Measurements of the jaw aperture were also made in 153 adults with skeletal muscle stress disorders. The group included patients with myalgias of the head, neck, or shoulders together with supposedly normal young adults in whom

Fig. 9.



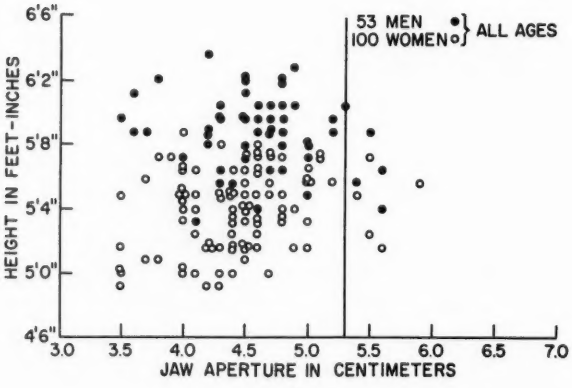


Fig. 10.

Fig. 9.—Correlation chart of the maximum jaw aperture at the incisor region with body height in 150 young adults and 10 children who had no evidence of jaw muscle spasm.

Fig. 10.—Correlation chart of the maximum jaw aperture at the incisor region with body height in 153 adults who had had prior attacks of skeletal muscle pain in the head, neck, or upper extremities.

either a history of trismus was uncovered or point tenderness was found in the masticatory muscles, often with referred pain evoked by palpation. When the values for jaw aperture were plotted against body height, no correlation existed in this group (Fig. 10), and the average values for jaw aperture were significantly lower than for the normal group, namely 4.6 cm. for men and 4.4 cm. for women. Age was not a factor in the difference. Furthermore, 89 per cent of the

normal subjects had an aperture of 5.0 cm. or larger (Fig. 9), whereas 84 per cent of those with skeletal muscle spasm had an aperture of less than 5.0 cm. (Fig. 10).

Only 2 patients in the entire group appreciated the fact that the vertical opening of their jaws was restricted, although in 6 patients the aperture was only 3.5 cm.

Response to Local Interruption of Myofascial Trigger Mechanism.—

Case report: The typical response of acute trismus to procaine infiltration of trigger areas in the muscles of mastication is shown in Fig. 11. In this illustrative case of a 26-year-old male medical student in good health, unilateral facial neuralgia and narrowing of the jaw aperture to 1.5 cm. occurred within 24 hours after the difficult extraction of an impacted lower left third molar, at the start of his Christmas vacation. During the previous 1½ years, there had been five

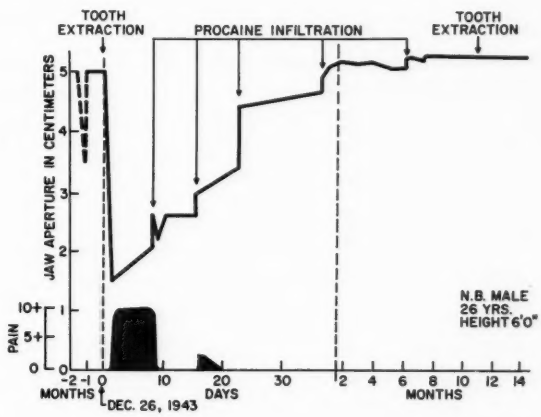


Fig. 11.—Response of pain (shown in black) and of restricted jaw opening to procaine infiltration of trigger areas in the masticatory muscles in a patient with acute trismus after the extraction of an impacted third molar. Note the immediate relief of pain gained from the first treatment and the steplike release of limited motion with each treatment.

episodes of pain and swelling around the impacted left third molar, and during one of these, the patient noted that opening of the jaws was somewhat limited. About a month prior to the extraction, the jaw aperture was normal, namely, 5.0 cm. He had no occlusal problem. He was subject to headaches and myalgias of the neck, shoulders, and back. These complaints were attributed largely to his heavy schedule of sedentary work and lack of free-moving exercise.

During the entire Christmas holiday, pain in the left side of the face, jaws, and temporomandibular joint was severe and constant and prevented sleep. Codeine, aspirin, and local heat afforded minimal relief. At the time of the first treatment, 1 week after the extraction, the patient still had intense left facial neuralgia with extreme sensitivity of the lower teeth on that side. Pressure on tender spots in the left masseter muscle evoked sharp homolateral pain in the lower posterior teeth, maxilla, and temple; this indicated the presence of trigger areas. The maximum vertical opening of the jaws was 2.1 cm., with deviation of the mandible to the right. The patient stated, however, that his mouth at this point felt wide open. There was no drainage from the operative socket.

The first treatment by infiltration of trigger areas in the masseter and external pterygoid muscles with 0.5 per cent procaine hydrochloride in physiologic saline terminated pain at once and increased the jaw aperture from 2.1 to 2.7 cm. (Fig. 11). Similar treatments of the left masticatory muscles at approximately weekly intervals brought about steplike improvement in the range of motion without regression between treatments. Just before the fourth treatment, the jaw aperture measured 4.7 cm., and afterward, 5.1 cm.

Unexpectedly 3 weeks later, a large bony sequestrum was discharged from the tooth socket.

Six months after the extraction, the jaw aperture measured 5.1 to 5.2 cm., but the mandible still deviated to the right. The *right* masseter and external pterygoid muscles were the seat of many trigger areas which referred pain widely, whereas the previously treated muscles on the left side were scarcely tender. Procaine infiltration of trigger areas in the right masticatory muscles eliminated the mandibular deviation. For several years of follow-up, the jaw aperture remained unchanged; a carious upper third molar on the right side was extracted without complications.

In this case of acute trismus caused by long-standing irritation and current surgical trauma to the jaw, the interruption of myofascial trigger mechanisms by local procaine infiltration afforded, first, spectacular relief of pain referred to the face, teeth, and temporomandibular joint, second, steplike release of the restricted vertical opening of the mandible, and third, correction of the abnormal lateral movement of the mandible.

Although pain was unilateral, masticatory spasm was bilateral, and it was necessary eventually to inject muscles in spasm on *both sides* of the face to re-establish normal vertical and lateral movements of the mandible. The passage of 5 months' time, in which local treatment of the muscles was held in abeyance, had failed to resolve the residual muscular dysfunction.

PROCAINE INFILTRATION OF TRIGGER AREAS

The accurate infiltration of procaine into trigger areas is in our experience the most certain method of interrupting the feedback cycles responsible for myofascial pain syndromes. If carried out with scruplous attention to a sterile technique and precautions against idiosyncrasy to procaine, hazards are minimal. Procaine is still regarded as the safest of the local anesthetic agents.[38,39] However, the patient is first questioned concerning allergic reactions to procaine, and if a suggestive history is obtained, it is not used.

For intramuscular infiltration into trigger areas, a comparatively low concentration of procaine is injected (0.25 to 0.5 per cent) and the total dose, which is small, is spread over a period of time. The dose usually does not exceed 100 mg. (20 ml. of a 0.5 per cent solution). When the concentration is raised to 1.0 per cent for intramuscular injection, transient minor toxic effects resulting from the central actions of procaine such as excitement, giddiness, ataxia, and impairment of hearing may appear in one-half of the patients.[40]

The question has been raised as to whether a concentration of procaine as low as 0.25 per cent possesses real pharmacologic actions. Tainter, Luduena, and Hoppe[41] have answered this question in an experimental study on the duration of sensory nerve block for concentrations of injected procaine hydrochloride that ranged from 0.1 to 2.0 per cent (Table I). After injection of a 0.25 per cent concentration, complete anesthesia occurred in all the tests and, on the average, lasted 20 minutes in the external canthus of the rabbit's eye and 12 minutes in the sciatic nerve of the guinea pig. Our observations on patients with myofascial pain

syndromes suggest that such a period of conduction block is adequate to extinguish the peripheral myogenic focus and associated pain cycles in the stress disorders of the skeletal muscles.

For procaine infiltration of trigger areas, through a single skin puncture the needle is moved rapidly in and out to reach all layers of the muscle and to pepper the trigger area thoroughly while at the same time small amounts of the solution are continuously injected. Dry needling of a trigger area is by itself sometimes effective in extinguishing the reverberating pain circuits. The total volume used in treating any one trigger area may be only 0.5 to 1.0 ml. By this technique, it is virtually impossible to introduce any appreciable amount of procaine directly into the blood stream.

There is *no epinephrine* in the solution of procaine that we employ. In the dental use of local anesthetics for nerve block, it is the epinephrine which creates the hazard if the solution is accidentally injected into a blood vessel. Epinephrine is very much more toxic when given by vein than when injected into muscle or other tissue spaces, whereas this is not true of procaine.

My approach to trigger areas in the masticatory muscles is external, through the skin. On withdrawal of the needle, hemostasis by immediate and sustained pressure on the injection sites avoids ecchymosis. In the case of the masseter and temporalis muscles, infiltration of trigger areas is relatively simple. The pterygoid muscles are less accessible, but can be reached by an external approach if the coronoid process of the mandible is displaced forward by propping the mouth open (Fig. 12). The intraoral approach to the internal pterygoid muscle can also be employed, unless trismus is so marked that the limited opening of the mouth precludes it.

The infiltrative approach to trigger areas in the trapezius and sternomastoid muscles has been described.[23-25]

TABLE I. LOCAL ANESTHETIC ACTIVITY OF INJECTED PROCAINE HYDROCHLORIDE

TEST SITE	CONCENTRATION (PER CENT)	NUMBER TESTED	COMPLETE ANESTHESIA	
			PER CENT	AVERAGE NUMBER OF MINUTES
External canthus of rabbit	0.1	12	75	19
	0.25	9	100	20
	0.5	36	100	24
	1.0	19	100	31
	2.0	9	100	46
Sciatic nerve of guinea pig	0.125	5	40	3
	0.25	17	100	12
	0.5	65	100	27
	1.0	14	100	41

Data adapted from Tainter, M. L., Luduena, F. P., and Hoppe, J. O.: The Trend to More Potent Local Anesthetic Solutions in Dentistry, Oral Surg. 6:645-661, 1953.

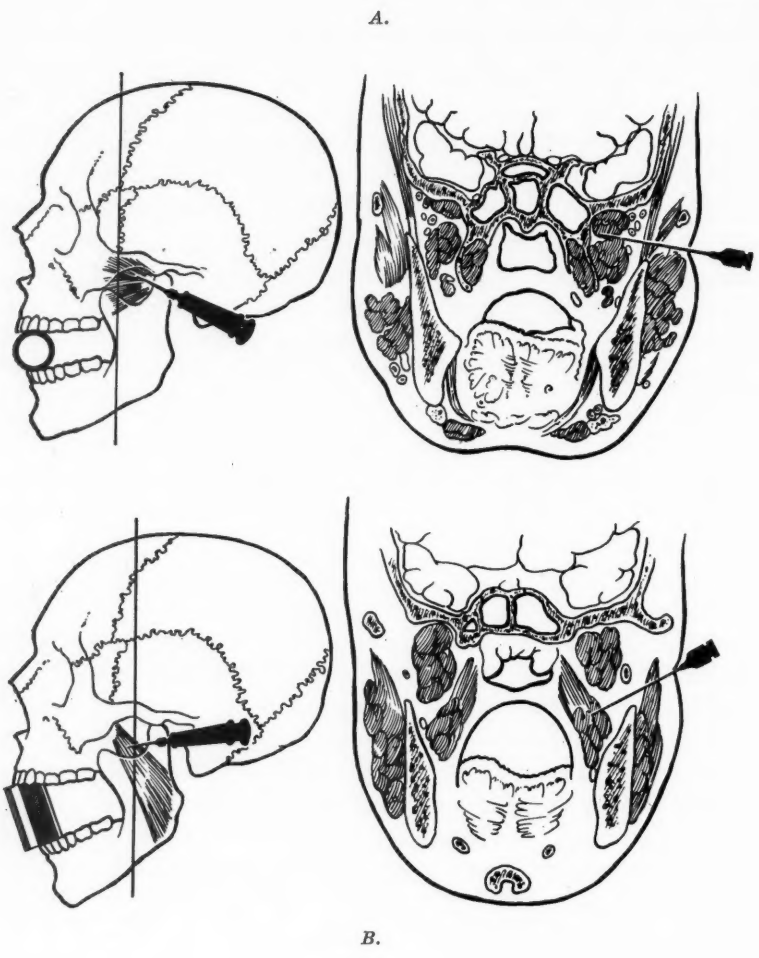


Fig. 12.—Approach to the pterygoid muscles for procaine infiltration. *A*, Needle in the external pterygoid. *B*, Needle in the internal pterygoid muscle. The vertical line on the outline drawing (at left) shows where the corresponding frontal section (at right) was made. The coronoid process of the mandible has been shifted forward by propping the mouth open. In *A*, the vertical opening between the incisor teeth measures 3.0 cm.; and in *B*, 5.0 cm. (Based on photographs in Kampmeier, O. F., Cooper, A., and Jones, T. S.: A Frontal Section Anatomy of the Head and Neck, Urbana, Ill., 1957, University of Illinois Press, sect. 7 and 8.)

Mechanism.—The mechanism by which local procaine infiltration relieves symptoms dependent on myofascial trigger areas is undoubtedly complex. Procaine is a versatile drug with other action besides that of blocking the conduction in nerve fibers. Procaine, locally, in low concentrations, has a curariform action on skeletal muscle and dilates blood vessels; in systemically larger doses, it reduces irritability of cardiac muscle, relieves itching, and has effects on the central nervous system like those of alcohol.

Dry needling alone occasionally accomplishes a similar, excellent therapeutic result. This is not to be regarded as a simple placebo effect. The needle may act

by releasing intracellular potassium, which in turn blocks nerve conduction temporarily. In some instances, the needle may serve to break up fibrous adhesions. Dry needling of trigger areas hurts much more than does the infiltration of 0.25 per cent procaine solution, and the use of procaine also enhances the effectiveness of the procedure.

ETHYL CHLORIDE SPRAY

Ethyl chloride spray, or other suitable vapocoolant, is a valuable agent for relieving skeletal muscle spasm, especially in its early stages.[5,6,9,21,22,31,42,43]

To carry out this procedure (Fig. 13), after locating the trigger areas the teeth are propped open to place a gentle stretch on the muscles in spasm within the limits of pain. The spray is then applied in slow, even, interrupted sweeps, in one direction only. It is started over the trigger area and travels in the direction of referred pain. Adjacent segments of overlying skin are thus systematically covered by the moving stream; no one spot becomes too cold. The skin is *not* frosted. The time interval between sweeps is lengthened if aching due to the cold develops. Although a longer application of the vapocoolant lowers deep tissue temperature,[44] we have found that, by our technique of application, conductive cooling of the muscles is insignificant and conclude that this is not essential to the neurogenic mechanisms by which surface cooling eliminates myofascial trigger areas.

Fig. 13.—Technique for applying a vapocoolant spray for relief of masseter muscle spasm. The mouth is propped comfortably at its maximum opening. Each sweep follows the muscle lines and travels toward and over the related pain reference zones. The patient is seated.

This process of intermittent spraying of a muscle group occupies a minute or two. The prop is then removed from between the teeth and active motion of the mandible instituted. If the jaw aperture has increased, a larger prop is introduced into the mouth and the spraying repeated. Graduated sizes of corks may be conveniently used.

Precautions are taken to protect the patient's eyes and to avoid his inhaling the vapor, especially when ethyl chloride, which is a general anesthetic agent, is used. Equally effective and safer is a vapocoolant mixture of fluoromethanes,[45,46] which has no general anesthetic action and is not flammable. In the case of flammable and explosive materials such as ethyl chloride spray, sources of danger in the form of an electric spark or open flame must be eliminated.

If the therapeutic response to the spray is definite but incomplete, the treatment is repeated at intervals of a few days, or oftener, as indicated. If satisfactory improvement is not secured by the vapocoolant spray, an excellent result may still be obtained by procaine infiltration of the trigger areas.

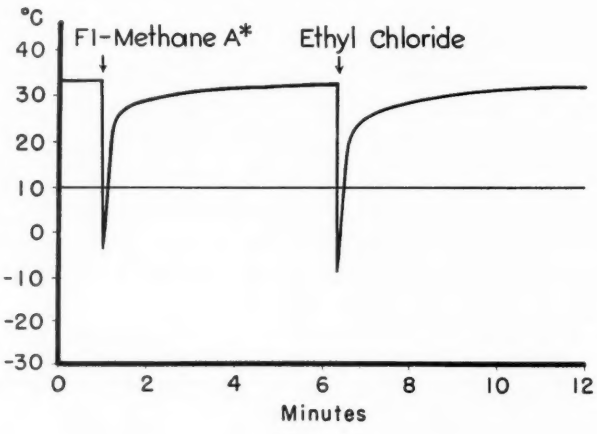


Fig. 14.—Comparable effects on skin surface temperature of two vapocoolant sprays. Each spray was applied through a "fine" nozzle (diameter 0.005 inch) continuously for 2 seconds, starting at the arrow. The skin surface temperature was recorded at 2-second intervals by iron constantan thermocouples (Leeds and Northrup Speedomax). (From Weeks, V. D., and Travell, J.: How to Give Painless Injections, A.M.A. Scientific Exhibits Volume, New York, 1957, Grune & Stratton, Inc., p. 320).

*Fl-methane A was a mixture of dichlorodifluoromethane (15 per cent) and trichloromonofluoromethane (85 per cent).

Mechanism.—The vapocoolant spray is a physical agent in a pharmacologic package, or "cold in a bottle."[22] Its clinical efficacy in stress disorders of the skeletal muscles is the result of the momentary sharp dip in skin temperature to about 0° C. or lower, with rapid rewarming (Fig. 14). Conductive cooling of the muscles themselves is not essential to the therapeutic result.

The cold shock and rapidly changing temperature gradient are thought to induce an afferent barrage which modifies the central excitatory state and so blocks the stream of noxious impulses from the muscles. Pain and cold sensations both travel in the spinothalamic tracts and terminate in the same higher centers; nerve impulses traveling over a given pathway may either initiate a response or block it.

It seems certain that brief *refrigeration anesthesia* of cutaneous receptors and *counterirritation,* that is, a strong input of stimuli, both enter into the neurophysiologic mechanism by which the vapocoolant sprays terminate painful muscle

spasm and referred myofascial pain. The prompt restoration of a normal input from the muscles by passive stretching and active motion seems also to play a role.

CONCLUSIONS

1. When spasm of skeletal muscles develops as the result of diverse stresses, it is likely to outlast the precipitating causes.

2. Stress disorders of the muscles of mastication may simulate organic disease of the mandibular articulation.

3. Trigger areas in the masticatory and certain neck muscles refer pain to the temporomandibular joint, teeth, gums, face, and cranium according to specific patterns and also give rise to specific nonpainful concomitants such as localized sweating, lacrimation, coryza, salivation, dizziness, and tinnitus.

4. The patterns of referred myofascial pain and their autonomic concomitants, like referred visceral pain, can be used in reverse to trace the pain to its source.

5. Therapeutic procedures should be directed to myofascial trigger areas rather than to reference zones where pain is felt.

6. Healthy teeth that serve as reference zones for trigger areas are rendered hypersensitive to ordinary pressure, heat, and cold and are, as well, painful in the absence of these external stimuli.

7. The aperture between the incisor teeth in adults of average stature and without spasm of the masticatory muscles measures at least 5.0 cm. for men and 4.5 cm. for women.

8. Latent spasm of the masticatory muscles predisposes to acute trismus and facial pain when prolonged overstretching of the jaw muscles occurs during difficult dental procedures.

9. The jaw aperture should be measured as a routine part of dental examination.

10. Procaine infiltration of myofascial trigger areas and/or application of a vapocoolant spray with gentle stretching of the muscles in spasm offers an effective method for terminating pathophysiologic stress disorders of the skeletal muscles, provided that steps are taken to correct any reactivating stress such as strain due to malocclusion, focal infection, metabolic and nutritional deficiencies, and contributory psychogenic tension.

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TEMPOROMANDIBULAR JOINT DISEASE AND TREATMENT

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TEMPOROMANDIBULAR JOINT DISTURBANCES may be classified as traumatic and erosive (mostly due to attrition). Traumatic disturbances include malocclusions and/or nonoccluding molars in the presence of nervous tension and trauma due to accidental injury of the joint tissues. Erosive disturbances include wearing down of the condyle and injury to the fibrocartilage of the joint and its connecting tissues. Traumatism also may be a factor, and the articular cartilage may be split.

TRAUMATIC DISTURBANCES

Nervous tension can cause firm clenching of the teeth, especially at night, and is often accompanied by bruxism. During bruxism, no food is between the teeth and the great muscle tension carries the condyle to its highest position in the glenoid fossa. The lateral movements of the condyles are at their maximum. Bruxism will subject the molars and the joint to such a traumatic load that during a single night it will exceed the normal masticatory load for a month.[1]

Should the molars and the bicuspids be missing in either or both jaws, the sustained action of the tensed closing muscles will cause the angle of the jaw to be increased. This increase in angle, in turn, increases the distance from the top of the condyle to the symphysis at the rate of 3 mm. for every 5 degrees of increase. Therefore, when the teeth are in occlusion, the upper incisors are forced forward, and at the same time the condyle is forced up and back. Sometimes, the neck of the condyle is bent forward with or without a retrusion of the lower incisors and with a possible protrusion of the upper incisors.

Continued stress may eventually force the condyle back far enough to pinch the auriculotemporal nerve as it passes upward over the auricular cartilage. Since the lateral depth of the glenoid fossa is only three-fourths of the lateral diameter of the condyle, one-fourth of the condyle protrudes past the tympanic plate. Thus, the auriculotemporal nerve may be traumatized as it passes between the auricular cartilage and this projecting part of the condyle.

At the same time, the attachment of the interarticular fibrocartilage both anteriorly and posteriorly is being injured. The anterior part is injured by sustained tension, while the posterior part is injured by occlusal forces. The interarticular fibrocartilage (disk) is less than 1 mm. thick in the center and about twice as thick on the anterior and posterior borders. The disk does not extend distally over the

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top of the condyle beyond the center of the top. Thus, the fibrous attachment of the interarticular disk must take the impact in this region.

Should an accident force the chin back, a great and sudden stress is placed on the anterior attachment of the disk and the tendinous attachment of the upper head of the external pterygoid muscle. Both of these structures attach to the capsular ligament inside and outside, respectively.

EROSIVE DISTURBANCES

Two causative factors prevail in erosive temporomandibular joint disturbances. The first is the failure to secrete a proper synovial fluid. The second factor is that the irritation produced by this failure in secretion may initiate bruxism.

The normal synovial fluid is rich in lymph and carries a mucinoid substance that acts as a lubricant. For some reason, a partial and sometimes almost total suppression of the mucinoid constituent is observed which leads to an inflammation that simulates rheumatoid arthritis. Thus, injection of cortisone has become an accepted treatment. Cortisone has an anti-inflammatory effect, but this treatment is primarily symptomatic. No research has been done in which a normal synovial secretion has been promoted effectively. However, stimulation of the thyroid gland by the use of thyroid extract promotes an increase in mucin content of the secretion of the mixed salivary glands. This occurs in patients with hypothyroid activity.

Fig. 1.—A roentgenogram that represents the average of 50 normal young adults with complete dentitions and no pain. The condyle is 4 mm. downward from the vault of the glenoid fossa and 3 mm. in front of the tympanic plate.

SYMPTOMS OF TEMPOROMANDIBULAR JOINT DISTURBANCES

Some of the symptoms of temporomandibular joint disturbances are pain in the joint, especially on lateral or protrusive movements, clicking, pain in the lateral occipital area, pain referred to the ear, buzzing in the ear, muscle spasms, and derangement of function in a part supplied by some nerve that has a communicating

branch with the facial nerve. Pain in the horizontal fibers of the temporal muscle upon intraoral palpation of their insertion on the anterior surface of the coronoid process indicates that the condyle is being pulled distally, thus deranging the joint mechanism. This condition is evident when there is nervous tension with excessive clenching of the jaws. The mylohyoid muscle and the power muscles of mastication are supplied by the trigeminal nerve (third division), while the labial accessory muscles of mastication are supplied by the facial nerve.

A roentgenogram should be made of each condyle and its glenoid fossa. In an average individual, the condyle is 3 mm. in front of the tympanic plate (the distal wall of the glenoid fossa) and 4 mm. below the vault of the glenoid fossa. Any great variation in these distances indicates a possible traumatizing effect (Fig. 1).

Sometimes an eroded condyle is seen in the roentgenogram. If this erosion is extensive, the vault of the glenoid fossa may be perforated also. In rare instances, there may be a reaction in the temporal lobe of the brain immediately above the fossa. This center is concerned with dreams and hallucinations.

DIFFERENTIAL DIAGNOSIS

A differential diagnosis must be made as certain other face pains are encountered. Sphenopalatine neuralgia simulates a tic, except that there is no trigger

Fig. 2.—A half skull is viewed from below: *(A)* the second division of the trigeminal nerve, *(B)* the sphenopalatine ganglion, *(C)* the glenoid fossa, *(D)* a perforation through the vault of the glenoid fossa, *(E)* the anterior ligament of the malleus, *(F)* the chorda tympani, *(H)* the facial nerve, *(J)* the superfacial temporal artery, *(N)* the auriculotemporal nerve, *(O)* the external auditory meatus, *(P)* the anterior palatine nerve, and *(X)* the nasopalatine nerve.

zone. Also, this neuralgia produces symptoms that may be mistakenly diagnosed as temporomandibular joint disease symptoms. In treatment of suspected temporomandibular joint disease, a rapid, high tuberosity injection of 2 ml. of 2 per cent procaine followed by firm massage of the tissue injected, before any other treatment is undertaken, often completely alleviates pain. Many of these patients report continuing relief of all painful symptoms. A facial pain may be induced by an

excessively heavy posterior palatal seal or pressure at the incisive foramen by a denture. Sinus and ear inflammation and infected and impacted teeth are encountered frequently.

CAUSE OF TEMPOROMANDIBULAR JOINT PAIN

The mechanism of the entire mandibular joint is disarranged when the condyle is forced distally. The anterior part of the capsular ligament and the upper head of the external pterygoid muscle are put under great tension. The interarticular fibrocartilage may be split. Meanwhile, the posterior attachment of the fibrocartilage may be traumatized. A buzzing in the ear may be caused by the traumatization (during bruxism) of the anterior ligament of the malleus located in the glaserian (petrotympanic) fissure. The chorda tympani, a branch of the facial nerve, emerges through a canal at the medial end of the petrotympanic fissure and joins the lingual nerve that activates taste buds in the anterior two-thirds of the tongue. This nerve also may be traumatized by bruxism and cause burning or other discomfort in the tongue, such as a salty or metallic taste. The distal displacement of the condyle also may pinch the lobe of the parotid gland that lies behind the

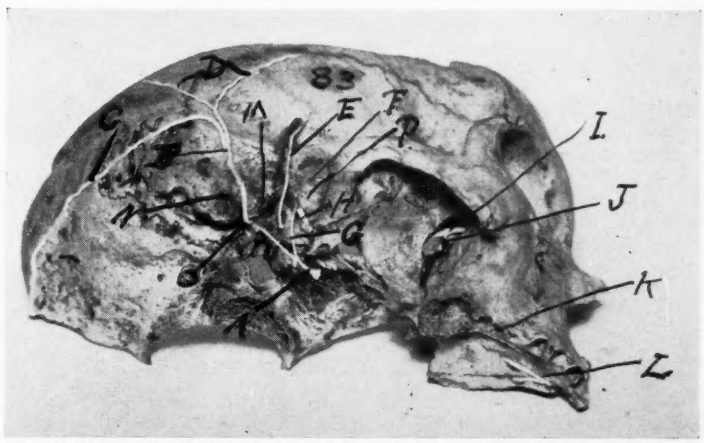

Fig. 3.—Occipital pain in temporomandibular joint disease is due to facial nerve involvement: *(A)* the facial nerve, *(B)* the posterior auricular nerve, a branch of the facial nerve, *(C)* the occipital nerve, a branch of the posterior auricular nerve, *(D)* the auricular nerves, *(E)* the auriculotemporal nerve, *(F)* a perforation into the cranium, *(G)* the chorda tympani, *(H)* the anterior ligament of the malleus, *(I)* the second division of the fifth nerve, *(J)* the sphenopalatine ganglion, *(K)* the anterior palatine nerve, *(L)* the nasopalatine nerves, *(M)* the external auditory meatus, *(N)* the mastoid process, *(O)* the stylomastoid foramen, and *(P)* the glenoid fossa.

neck of the condyle and thus cause a neuralgia of the facial, auriculotemporal, and some small nerve fibers in the gland (Fig. 2).

Interference with the facial nerve may cause disturbances in tissues far beyond the temporomandibular joint, because the facial nerve has communicating

branches with other nerves. Therefore, reactions and referred pain may be complex and widespread. The distribution of the facial nerve and its relation to the other cranial nerves must be known before attempting a diagnosis (Fig. 3).

Some of the same causes produce pain in the erosive type of temporomandibular joint disturbance. However, pain is caused also by the erosive action of an improperly lubricated joint. Jones[2] reports that an unlubricated joint under a light load wore the cartilage through to bone in 4 hours. Gonorrheal synovitis frequently attacks the temporomandibular joint.

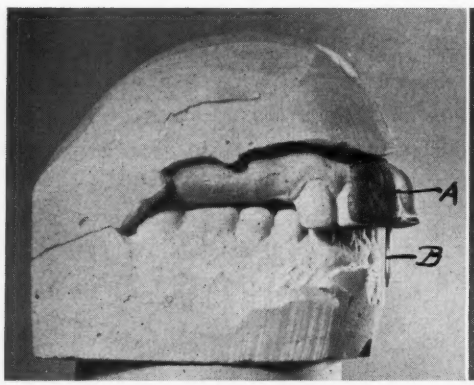

Fig. 4.

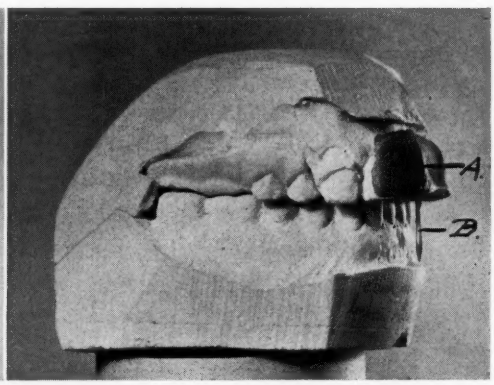

Fig. 5.

Fig. 4.—Casts of a 39-year-old patient with intense temporomandibular joint pain. The maxillary bicuspids and molars are missing. Shown are *(A)* the modeling compound to hold the stylus and *(B)* the stylus used to measure the retrusion of the lower jaw.

Fig. 5.—Casts of the same patient seen in Fig. 4. The vertical dimension of occlusion was opened 3 mm. at the central incisors. The measurement from the stylus *(B)* to the labial surface of the lower incisors indicates that the mandible is approximately 1 mm. farther posteriorly as a result of the increase in vertical dimension.

TREATMENT

Roentgenograms of both condyles should be made with the teeth in centric occlusion and the position of the condyles in the glenoid fossa noted. A psychiatrist is usually needed to ease nervous tensions, since these tensions magnify the symptoms.

Next the occlusion and number of missing teeth are determined. Articulated study casts are usually needed to help make a diagnosis. Then, the occlusion is equilibrated, if necessary, and an appliance may be constructed to act as a splint. The splint may be a removable restoration or a fixed one. A removable splint made of resilient material is tried before a more complicated fixed restoration is made.[3] If the splint increases the vertical dimension of occlusion 3 mm. on the anterior teeth, the condyle will move forward 4 mm. and move down from the vault of the glenoid fossa approximately 1 mm. The lower incisors will be retruded about 1 mm. (Figs. 4 and 5). We must equilibrate muscle tension by carefully increasing the vertical dimension of occlusion the proper amount, as disclosed by the roentgenograms (Figs. 6 and 7). Calipers must be used to measure the distance from the

gingival margin of the lower incisor to the gingival margin of the upper incisors with the restoration both in and out of the mouth. Often, a removable appliance worn at night will relieve painful symptoms.

Sometimes, cortisone may be injected to relieve inflammation. A high tuberosity injection of 1 ml. of procaine followed by 0.5 ml. of sodium psylliate injected into the synovial sac is another treatment. The sodium psylliate promotes a fibrous exudate that ultimately results in a thickening and fibrosing of the tissues. The action of procaine is twofold: it anesthetizes the region but it also has a side effect which often is beneficial.[2]

Several other factors have been determined concerning the temporomandibular joint. Some of these are: (1) testicular extract reduces the viscosity of synovial fluid compared to that of water, but sodium salicylate inhibits this action[2]; (2) a split interarticular disk will heal in the presence of synovial fluid[2]; (3) in the opening and closing movements of the jaws, movement takes place between the condyle and the fibrocartilage, while the grinding movement takes place between the mandibular fossa and the fibrocartilage[2]; and (4) chlorides and bicarbonates are plentiful in the synovial fluid, while the amounts of sodium, potassium, calcium, and magnesium are low.

Fig. 6.

Fig. 7.

Fig. 6.—A roentgenogram of the right condyle of the patient whose casts are seen in Fig. 4. The teeth are in centric occlusion. The jaw angle is 125 degrees, which is probably an increase of 4 or 5 degrees over the angle when the patient had a full complement of natural teeth.

Fig. 7.—A roentgenogram of the same patient as in Fig. 4. The vertical dimension of occlusion was increased 3 mm. at the central incisors. The condyle has moved downward about 1 mm. and forward about 4 mm. from the position seen in Fig. 6. An opening of 2 mm. at the central incisors would probably have been sufficient. The pain was relieved almost completely within 1 month. A mild antral pain persisted. A high tuberosity injection of 2 ml. of 2 per cent procaine into the region of the sphenopalatine ganglion completely relieved all pain. There has been no recurrence of pain for 1 year.

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OPERATIVE DENTISTRY

GOLD FOIL—A PRACTICAL RESTORATION

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MANY DENTAL EDUCATORS believe that the main reason for teaching the gold-foil technique is to assist the student in developing a higher degree of manual dexterity. They believe and teach that gold foil as a filling material has no place in practical dentistry. One well-known advocate[1] of this theory said, ". . . the time consuming malleted gold foil restoration is usually a firm requirement, even though we know that most of the gold foil in this country is used in dental schools. There is much taught in dental schools which is good but which cannot be applied directly to dental practice. My point is that our curriculum is, in many cases, ruled by tradition. We have been convinced that teaching the use of gold foil is the best method of teaching exacting technical procedures, although no one has yet demonstrated that an equal skill could not be developed in some other manner which might be more valuable."

Many times, in my teaching experience, I have had to justify my zeal for teaching and using gold foil to my colleagues and fellow dentists. I am just as zealous in the use of gold foil in practice as in school. The following fact should be taught to the dental student: gold foil is the most nearly perfect and therefore the most practical of all filling materials.

Black[2] said, "There can be no doubt but that the gold foil restoration leads the list of materials for efficient and permanent preservation of tooth structure." Skinner[3] states, "When used in the form of foil, it [gold] is an ideal dental restorative material from the standpoint of preserving tooth structure." Smith[4] writes, "Unquestionably the finest restorative material available in operative dentistry today, and yet the one which conserves the patient's dental tissue to the greatest possible degree is gold foil." Many writers have expressed these same opinions. I have read no article written by leading dental material researchers or by highly skilled dentists which would disagree with these opinions. From a purely operative point of view, foil takes second place to nothing else for use in the incipient stages of decay or erosion.[5]

DISADVANTAGES

The only three disadvantages to the use of gold foil are (1) its unesthetic qualities, (2) its difficulty of manipulation, and (3) its thermal conductivity. The first of these disadvantages, its unesthetic qualities, can easily be overcome by conquering the second disadvantage, its difficulty of manipulation. Gold foil has poor esthetic qualities only when placed in a poor cavity preparation. The poor color of gold can be overcome by placing it in a proper cavity outline form and properly condensing the foil. Proper outline form and proper condensation can be achieved through study and practice. Much has been written on cavity outline and its harmony with tooth form by Ferrier[6] and many others.[4,5,7,8] The third disadvantage, its thermal conductivity, is approximately the same as that of silver alloy, the most used filling material in dentistry.

REASONS FOR LACK OF USE

If gold foil is such a good filling material among so many materials which are no more than temporary cements, why is it not used more extensively in practice in the dental office? From considerable questioning and discussion with dentists, the reasons for not using foil can be divided into three main categories: (1) the economic factor for both the patient and the dentist, (2) more and faster services needed for more patients, and (3) lack of skill and confidence of the dentist.

Economic Factor for the Patient.—A young adult has initial caries in his anterior teeth. If these cavities are filled with silicate cement, over a period of a few short years the restoration will have had to be changed two or three times. Each time the size of the cavity must be increased until finally it is necessary to replace the silicate with a porcelain jacket crown. The tooth may even be lost because of acid irritation from the silicate cement.

Even when class V cavities are carefully filled with silver amalgam and the restorations polished, the gingivae recede because of irritation of the alloy. This results in decay gingival to the filling and further extension of the cavity, until a full crown is required to properly repair the tooth. There are exceptions, but in most mouths this has been found to be the rule.

Dental care should be considered as a long-term investment. As such, the patient cannot afford to have several temporary restorations made and even gamble on the loss of the tooth. One gold-foil restoration placed when the cavity is small will restore the tooth for the life of the patient.

Economic Factor for the Dentist.—Many dentists feel that a gold-foil restoration requires too much time to make. Inexperienced dentists will find the placement of a gold-foil restoration a long and tedious job. However, it can be done in stages as other gold work is done. The cavity is prepared in one sitting, the foil condensed in another, and the filling finished and polished at a third appointment, if necessary. A proper presentation to the patient will substantiate a fee that is economically sufficient to the dentist and yet just to the patient. The satisfaction of doing the best job possible with the materials available is another reward for the dentist.

More Service for More Patients.—Many dentists feel that more and faster service is needed for more patients because of the shortage of dentists. Once again, dental care must be viewed as a long-term program. Over a period of years, time is actually saved by using the permanent gold-foil restorations rather than placing several temporary silicate cements in the same cavity.

Lack of Skill and Confidence.—Lack of skill and confidence is probably the most frequent reason for not making gold-foil restorations. With such a fine filling material, the responsibility of the profession is to make gold foil available more often to the public. Dentists should avail themselves of every opportunity to become more proficient in its use.

INCREASING SKILL AND CONFIDENCE

Five steps are necessary to increase the skill and confidence of the dental profession in the use of gold foil.

1. The attitude of many dental educators must be changed before the use of gold foil by dentists can be increased. Gold foil is discouraged by some deans and chairmen of departments in our schools. Those who discourage the use of gold foil should study and reconsider the relative merits of restorative materials.

2. An increased number of gold foil restorations required in dental school will increase the skill and confidence of the student. This requirement may decrease the number of other operative requirements, but if a student learns to place a good gold-foil restoration, his abilities to make other restorations increase. This material has been called the "yardstick of operative ability and dental restorative perfection."[8]

3. Teachers must convey to students a thorough knowledge of the advantages of gold foil as a filling material. This knowledge makes students desirous to make this service available to the public and realize that it is their duty to their patients to become skilled in its use. Students must also be taught the manner of gold-foil presentation so that the patient realizes the advantages of the best, though more expensive, material.

4. A student must be made to realize that skill is acquired only through practice and that his skill is just beginning to mature at the time of his graduation. An old axiom heard as a child is apropos: "That which we persist in doing becomes easy, not that the nature of the task has changed but that our ability to do it has increased." It should be impressed upon the students that the best time to increase their ability is immediately after graduation. It is then that they usually have the most time available to do so.

5. Undergraduate students should be encouraged to join a gold-foil study club immediately upon graduation. This is the finest and most practical way to become efficient and skillful in the use of gold foil. Working with other men interested in refinement of their operative techniques spurs one on to further refinement of his own skills.

SUMMARY AND CONCLUSION

Gold foil is the most nearly perfect filling material available. Through proper cavity preparation, it is an esthetic restoration. Through greater skill and confidence of the dentist, gold foil is a practical and economical filling material. The dentist acquires this skill and confidence by persistently placing gold-foil restorations and study club activity.

Educational institutions are failing to graduate dentists who can render the best service to the public if they are not teaching the use of gold foil as a practical filling material. Although the use of the gold-foil technique is a good method of acquiring manual dexterity, that alone is insufficient reason for its use in a dental school.

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RESTORATIONS FOR CLASS V CAVITIES

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GINGIVAL-THIRD RESTORATIONS are supposedly simple since they involve only one surface of a tooth, but they present various problems. These problems range from esthetic considerations in the anterior teeth to soft tissue protection, accessibility, and durability in the posterior teeth. The use of the gold inlay offers solutions to the problems with gingival-third cavities involved in posterior teeth.

CLASS V GOLD INLAY

There can be little question of the supremacy of gold foil as the material of choice for Class V restorations in general. However, in the molar teeth the impracticability or impossibility of placing a rubber dam often precludes the use of foil.

Often amalgam is used without the aid of the dam. After observing many of these amalgam restorations, I am convinced that the gold inlay renders a better service. The gold inlay is recommended because (1) proper contour and an accurate gingival seal are readily obtained, (2) a favorable beveling situation usually prevails at the cavity margins, especially the critical gingival margin, (3) the cavity preparation is not likely to undermine the mesial and distal walls when surface extension demands are met, (4) thermal shock is minimized or easily controlled, since the bulk of the casting may be reduced before cementation, and (5) maintaining a dry field to properly place and condense amalgam presents a greater problem than the cementation of a fitted and finished casting.

CAVITY PREPARATION

Cavity preparation for an inlay requires no more skill than for an amalgam restoration. The use of short-shank burs is highly desirable at times for second and third molars, especially on the lingual surfaces. Near parallelism of the walls, which are of necessity short, combined with cleanly cut internal form, provides resistance and retention. Judicious use of pins, pinholes, or channels can increase retention tremendously.

WAX PATTERN

The pattern is the crux of this procedure, and it may be obtained by either the direct or indirect method. In either method, a tray must be made for the cavity.

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TRAY CONSTRUCTION

A rather rigid metal, such as soft nickel-silver or "German silver," approximately 26 gauge, has proved satisfactory for construction of the tray. Some dentists have found Ash's Metal more easily adapted and shaped than the German silver. Ash's Metal is a high-tin alloy, readily obtainable in roll form. However, it has the disadvantage of lack of the rigidity or stiffness which is necessary for unusually large cavities. With care, either material will make an adequate tray.

A rectangular strip of metal approximately 0.5 inch wide and 1 inch long is cut from the sheet. One end is festooned with curved shears to cover the gingival margin. The metal strip is then adapted with Peeso or Robinson collar pliers to cover the preparation, bending the mesial and distal edges slightly around the angles of the tooth. Then, the occlusal two-thirds of the strip is bent away to form a handle for a needle holder or hemostat forceps to grasp. The edges are smoothed with a disk, and the tray is shaped to allow an excess contour of wax.

DIRECT TECHNIQUE

A cone of blue inlay wax that will overfill the cavity is formed. The base of the cone is attached to the tray by heating the tray and firmly adapting the wax. The tip of the cone is softened slowly and covered with a layer of black inlay wax (S. S. White No. 5).

When the black wax has just lost its gloss, the tray is carried into the mouth with a needle holder or hemostat pliers and is forcibly adapted to the lubricated cavity. The tray is seated in a slightly gingival direction, which usually produces a slight blanching of the gingival tissue, indicating complete coverage at the gingival margin of the cavity. A slight rocking or rolling motion with one hand as pressure is applied with the fingertips of the other directly into the cavity gives good adaptation. An air stream is directed against the tray to cool the wax to room temperature.

The tray is removed with the pattern attached, and the pattern is carefully checked for complete adaptation. Every angle and detail must be clearly delineated or the wax is removed and another cone is formed and adapted.

If the pattern is complete, most of the excess wax beyond the cavity margins is trimmed with a pointed Bard-Parker lancet No. 11 in a No. 9 handle. The wax is cut against the tray as close to the mesial, distal, and gingival margins as possible, but an excess of several millimeters is retained beyond the occlusal margin. A wax carver, such as a Hollenback or Craig, is introduced along this occlusal margin, and the pattern is pried off of the tray in one piece. The pattern is picked up with a cotton pliers and held by the excess wax extending beyond the occlusal margin. The cavity is wiped dry of lubricant or seepage, and the pattern is readapted into the cavity with strong finger pressure.

The occlusal margin is sealed with a warm plastic instrument such as an electric wax spatula to secure it in place. The mesial, distal, and gingival margins are carved with a cold, sharp carver, while maintaining slight pressure against the pattern either with the finger or a blunt instrument. The occlusal margin is carved with a sharp, cold carver as the pattern is steadied with a slight inward pressure. If the internal form of the cavity is correct, very little pressure is needed.

A single or staple-type sprue pin is attached, and the pattern is withdrawn. The sprue pin may be held in the hemostat while the assistant applies an air stream at just the right instant for cooling.

INDIRECT TECHNIQUE

A tray is made in the same manner as for the direct technique. However, a shorter handle is desirable to allow easier attachment of the impression material to the electroforming paddle.

A variety of impression materials is available for this technique. Some of these are: (1) red or brown modeling compound, preferably of the low-heat type, used with dry heat, (2) elastic materials, such as Mizzy "Trulastic," which must be bonded to the tray with modeling compound, (3) Dietrich's impression material, which requires perforations to secure it to the tray, (4) the newer silicone materials, which require an adhesive to bond them to the tray and are relatively slow setting, and (5) ordinary inlay wax with a soft-wax liner (S. S. White No. 5). These materials may be plated with copper and will make excellent dies when properly handled.

The technique of making the impression is similar to the direct method, except that the impression material is not removed from the tray. Forming a cone or wedge of material, softening the tip, adapting the tray under steady or rolling pressure, and allowing the impression material to cool or set before removal are the basic principles involved. Internal angles must be sharp and marginal outlines must be clearly readable in the finished impression.

The impression is metalized and mounted on a suitable paddle for electroforming (copper plating). The manufacturer's directions are followed explicitly.

Plating overnight or longer will usually build up a sufficient thickness of copper. A stone base is more easily poured than low-fusing metal since the stone requires no boxing. When separated, the die is trimmed at the gingival, mesial, and distal margins to allow easy carving and finishing of the pattern. The die is warmed and lubricated, and the pattern is waxed to the desired contour.

It is helpful to make a direct pattern showing complete internal cavity detail, but with marginal excess, at the same time the impression is made. This pattern can be made first, using the same tray and then flicking the pattern off, cleaning the tray, and making the impression. When this pattern is adapted into the die cavity, it takes only a few moments to complete the marginal carving. This step eliminates the wax shrinkage so often encountered when attempting to use molten wax on a metal die.

TEMPORARY FILLING

Between appointments, the cavity is sealed with a baseplate gutta-percha inlay which is cemented with surgical cement (quick-setting zinc oxide and eugenol) so as to slightly depress the gingival tissue. This procedure ensures that there should be little difficulty in maintaining a dry field when the casting is cemented in place. It is more difficult to maintain a dry field consistently in a freshly cut cavity in order to properly place and condense an amalgam restoration.

FINISHING THE INLAY

The pattern is cast with type A soft gold and may be fitted, finished, and polished on the die. Relief of the axial wall for insulation and proper marginal seating is necessary, as with the direct pattern technique.

Very little, if any, finishing is needed after cementation if an accurate die is obtained. Consistently better contour with these castings than with amalgam results in less gingival recession and less recurrent caries.

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MISCELLANEOUS

THE EXPLOSION OF KNOWLEDGE AND CONTINUING EDUCATION

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EDUCATION IS THE MOST OBVIOUS COMMON DENOMINATOR among all of us these days—whether we are scientists, professional men, public servants, or businessmen, in which category I place myself. I bring to the subject only the credentials of a businessman who has long been interested in it.

Lest you be alarmed, let me hastily add that I will cover only a small section of the pervasive subject of education and I do so as a layman. Let me be emphatic on that point. My amateur standing in this field is very dear to me. It allows me to be quite irresponsible in proposing impractical ideas. I can be a little careless with statistics and lastly, if I am caught in a debate and, most likely, losing fast, I can always extricate myself by assuming an appearance of injured dignity and severely announcing that I do not wish to pursue the matter further lest I jeopardize my status.

I have chosen as my title one which should be fully descriptive, "The Explosion of Knowledge and Continuing Education." It is my thesis that in the midst of an explosive expansion of technical knowledge and techniques, many of our political and educational concepts and procedures have been rendered obsolete. A case in point is the economic doctrine of laissez faire upon which much of our political thinking rested during the past two or three centuries. Laissez faire presupposes a state of equilibrium. The slow adjustments of the past were suited to a gradually moving equilibrium but no longer fit the rapid pace of current change.

Similarly, in education, a premium must be placed nowadays on adaptability. A professional man can no longer expect to spend a lifetime practicing the same skills and applying the same body of knowledge with which he started his career.

Only, therefore, by continuing our education throughout our lives can we cope with the new situations which will confront us. Self-development will become relatively more important. Formal classroom training will have to emphasize the basic tools of self-adjustment.

As individuals and as a nation we have much at stake in this matter of adaptability to change. If we are complacent, if we equate education simply with formal

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Read before the American Denture Society in New York, N. Y.

schooling, we cannot hope to compete with the realists who see education as an urgent lifetime task and who are willing to pay what it costs in time and money.

THE EXPLOSION OF KNOWLEDGE

The current pace of scientific progress is so familiar that I need not labor the point. However, I cannot resist giving you two recent illustrations of the explosive force behind the impact of science on our society. Force is the product of *mass* times *velocity*. One of my illustrations is a measure of mass, and the other of velocity.

As to mass, James Killian, Chairman of the Board of M.I.T. and formerly head of the President's Science Advisory Committee, points out that there are now published throughout the world each year 55,000 journals containing 1,200,000 significant articles in the physical and life sciences alone. In addition more than 60,000 scientific books and approximately 100,000 isolated research reports are published annually. Such an output is certainly massive.

Now for velocity let me cite Dr. Ellis Johnston of the Operations Research Office of Johns Hopkins University: "Up to A.D. 1,000," he said in a recent speech, "weapons had a lifetime of about 400 years; from A.D. 1,500 until the beginning of the twentieth century, a lifetime of about 50 years. But today weapon systems have a lifetime of about 5 years and tend to be obsolescent by the time the first units come off the assembly line."

With these two citations no more need be said to illustrate the explosive nature of knowledge. I am sure each of you could recall countless personal observations of the accelerating process by which each new discovery opens up wider vistas for further comparisons, conjectures, and investigations leading to another breakthrough on the frontiers of knowledge.

The impact of expanding knowledge is not limited to physical and material progress. Each practical application of science has reflections in our changed social habits. The advent of the automobile is one of the simplest illustrations of what I have in mind. The development of a practical, inexpensive, foolproof internal combustion engine has had consequences unimagined by Henry Ford. The hunt for gasoline to feed it certainly accelerated the social revolutions of the Middle East. Here at home the automobile has stimulated road building, suburban living, family mobility, new words, new horizons, new concepts of life.

RAPID SOCIAL CHANGES

A shorter work week, household appliances, and factory-prepared foods have literally manufactured leisure. And for the first time ever, a nation is not living anxiously on the edge of want but has more than the necessities of life. It has ample margins above the level of subsistence and time to enjoy the products of its ingenuity.

These rapid changes in things, and somewhat slower changes in individual habits, are many times more rapid than the change in social concepts. Consequently, there is a lag in community behavior and an even slower evolution of national customs.

Thus a dangerous divergence is imminent between man's ingenuity and his capacity to master the intricate social problems which he has created.

During the past we believed that the effect of innovations would modify, by slow degrees, our group habits in gradual adjustment to the countervailing forces as they emerged. Thus the economists of the eighteenth and nineteenth centuries, such as Smith, Malthus, Ricardo, Mills, Marx, and Veblen, described the way they thought inexorable social forces would shape our society. This was reminiscent of the preordained course of a Greek tragedy. They did not consider how political steps could be taken which might modify or even avoid unfavorable social consequences. Laissez faire dominated their thinking and the failure of Robert Owen's utopian communities and others such as Brook Farm and Oneida seemed to confirm the correctness of their attitude.

Even two or three decades ago many people in this country were so reluctant to depart from a fatalistic approach to social change that the word "planning" acquired all sorts of sinister overtones. A planner, instead of being considered as a forward-looking leader, a person thoughtful of the future, was sometimes even suspected of conspiratorial purposes. Planning commissions and social projects were ridiculed and the words became a political liability instead of an asset. They were almost synonomous with scheming.

I believe that time has changed this and the words have been restored to an honored place in our political dictionaries. The majority now agree that we must project our future. We must plan for it; we must take steps to avoid the undesirable consequences of our ingenuity. We have concluded that a skill similar to that which could design our buildings can design our communities. Perhaps also, the procedures which make our industrial organization successful can be applied in appropriate fashion to the organizations of our government.

OUR SUCCESS WILL DEPEND UPON THE LEVEL OF OUR EDUCATION.

In order, however, to maintain our democratic form of government and so preserve the reasonable privileges and rights of the individual, our attempts to control and guide our social and economic directions must come by the authority of an aware citizenry. Indeed, there must be more than an awareness or an acquiescence, but a positive cooperation with the various programs and restraints by which a complicated society can remain free and develop with minimum friction.

Such cooperative effort can only be expected from a people who are perceptive and educated. It can only exist when a high enough proportion of the people understand the social processes through which they are living.

Of course it is a platitude to say that our individual and national success will depend upon the level of our education. But because it is trite does not make it less true. There is, moreover, a new urgency. Conditions, attitudes, and patterns are changing so rapidly that we cannot feel that what we learned in our early formal schooling will remain applicable throughout our lives.

The physics and chemistry I learned in college are certainly inadequate today. New emphasis upon our social studies and the behavioral sciences have matched in theory and experiment our expanding knowledge of the physical world. In no

important field can we be content with the applicability of knowledge acquired during our formal schooling. Never has there been greater need to keep abreast of the changes that surround us.

There you have my message in a nutshell. We have to keep on learning every year, but most particularly as we grow in maturity and achieve influence within our respective circles.

ARE WE PREPARED TO GUIDE OUR FUTURE?

Just how good a job are we doing of continuing our education? I am not sure, but I believe we may have taken too complacent a view of our performance. I think it is worthy of a few minutes' self-examination. Are we as enlightened as we would like to believe? Are there valid tests by which we might compare the level of our education with other nations? Let's have a look at some items of measurement even though they certainly are not conclusive.

Item 1.—We have almost universal literacy. Yes, 97.5 per cent of our citizens are literate in the technical sense. But this is not very different from recent comparable figures which showed 96.5 for France, 98 for England, 98 for Germany, and 90 to 95 per cent for Russia.

Item 2.—We place great stress on the belief that real progress exists only where the teacher is free in his teaching and the student in his learning and where the scientist is undominated in his research. This is undoubtedly true over a long period of years, but the Russians and Nazi Germany have piled up a lot of short-term evidence to the contrary. Many of our scientists and industrialists have visited Russia and returned to tell us that the Soviets have drawn equal or surpassed us in certain scientific and technical areas. This is no place to add up a score, but the Soviet Union has certainly shown during the last 30 years that basic and applied science can exist and grow unnurtured by the spirit of pure freedom.

Item 3.—Of our boys and girls, 80 per cent now graduate from high school. A third of them go to college. No other country in the world has such a record of formal education. There is no doubt that in the United States we have more youth-years' exposure to classroom teaching than any other country in the world. This, however, is not the whole story. Our vacations are longer and extracurricular opportunities are more enticing. Graduates of the gymnasium in Germany or the lycée in France are age for age almost 2 years ahead of our high school graduates here. Although in this country, the proportion continuing their schooling beyond age 18 is five times greater than in Europe, the proportion who go beyond college and achieve graduate degrees in the United States is about the same as graduate from European universities, and there is a rough equivalence between the two attainments.

Item 4.—Adult reading might be used as a measure of cultural level. I hope this is not an accurate scale, because statistics seem to show that about three to four books per year per capita are read in the United States compared to seven to ten in England. Russia claims double this amount, but there is no way to substantiate the figures in that country. A recent Gallup poll was even less flattering

in estimating that besides reading less per capita than the Australians and Canadians, we read per capita half as many books as the West Germans and one-quarter as many as the Finns.

These estimates are confirmed by statistics on library circulation as well as book sales to the public. UNESCO published, in 1957, statistics which showed that in library utilization the United States ranked behind the United Kingdom, New Zealand, Denmark, Sweden, and Finland. Now one last measure—in the total of first editions published, Russia leads with 21,000 titles, the United Kingdom had 14,000, France 11,000, and the United States 10,561.

Of course all these may not be accurate measures of adult education. There are many entrances to the mind. The quality and quantity of the entering material are important but the impact is most important of all. Who would be willing to say that a first-class television program is less enlightening than the vast majority of paperbacks in every drugstore. The profusion of magazines, newspapers, pamphlets, and experiences derived from our mobility are, of course, important factors in our continuing education, but let us not forget that we may not have as great pre-eminence as we would like to believe.

WHAT SENSIBLE ATTITUDES SHOULD WE ADOPT?

Now is the moment in a talk when the speaker, knowing that he will soon be finished, hopes to arouse his audience.

A favorite gambit is to compare our sorry state of affairs with the smoothly efficient Russians. I will not insult your intelligence with such a foolish statement. Who would want their system even if they are as totally accomplished as some who have cashed in a 2-weeks' visa would have us believe.

I could hope to arouse you by listing a number of courses of action which you should follow and warning you of the dire consequences if you do not comply. But you and I know that adult or continuing education is not an enterprise to be taken up like golf or double acrostics or Sunday painting. It is not a single event or an immediate change but a continuous condition of living.

There are, however, a few general steps toward this end that most of us are taking to a greater or lesser extent, depending upon our awareness of the limitations and rapid obsolescence of our knowledge. I hardly need tell a professional group such as the American Denture Society how great is the need to take these steps, which might be summed up as follows:

First.—When our youngsters leave the formal part of their educational experience, let us make sure that they have the basic foundation which will be the common denominator of any career or profession which they will follow. These common denominators can be more quickly enumerated than they can be gained. At whatever level young people leave their organized schooling, they should be started on the way toward teaching themselves—learning how to read and observe critically, how to reach rational conclusions, and how to delight in the wealth of ideas and material things which they have inherited.

Second.—All of us should emphasize the importance of semiformal education that goes on in industry and the professions. Actually, the number of people

attending some sort of organized instruction in a factory, office, or store is greater than the total attendance at the colleges and universities.

Third.—There are many millions of adults attending, with varying regularity, classes organized to cultivate their intellects and so enrich their lives. It is difficult to calculate how many pursue this form of continuing education, but 3 years ago, the President's Committee on Education Beyond the High School estimated it to be in the neighborhood of 50 million. Whatever the figure may be, it is surely more today than it was at that time.

Fourth.—We can read more than was ever assigned us by our instructors. We have a good free library tradition in the United States. To be sure, the cities are better provided than the country, but books are available without cost for those who want to take the trouble to pick them up and read them. With the proliferation of cheaper, paperback editions, possession of books is within the reach of almost every family in sufficient variety to satisfy the basic foundation of learning how to read critically. By reading and discussion, we can pursue our own programs of self-development unfettered by the mechanics of our degree-granting institutions.

There are, of course, many other roads to continuing education. Radio and television provide them, although some of the best organized of the latter begin somewhat early in the morning.

The problem is not the amplitude of the facilities for continuation of education but how they are used. Certainly there are enough in this country to satisfy the appetite of anyone who is willing to forage for them.

SUMMARY

There you have my total message. I can put it as follows: We are in the midst of an explosion of knowledge in which one decade outpaces the intellectual awakening of an entire century before the twentieth. It is massive. Social and economic change is more rapid than ever before. This affects our lives, our careers, our political institutions, and indeed our national survival. We can no longer risk the slow groping of evolutionary adjustments. The story of civilization is approaching a climax in which the surviving characters will be those who can step from the pages of the book and influence the writing of the next chapter.

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THE AMERICAN BOARD OF PROSTHODONTICS

CHARLES H. JAMIESON, D.D.S.
Detroit, Mich.

THE 1959 EXAMINATION BY THE AMERICAN BOARD OF PROSTHODONTICS was held August 31 to September 5 at Northwestern University, School of Dentistry, in Chicago. Seven candidates successfully met the Board requirements and have been certified to practice the specialty of prosthodontics. Three of these candidates took the clinical examination in fixed partial prosthodontics. Dr. Carlisle C. Bastian of New York City, appointed by the Council on Dental Education of the American Dental Association, acted as Consultant Examiner in this clinical area.

Dr. S. Howard Payne of Buffalo, New York, and Dr. M. M. DeVan of Philadelphia retired as Board members, having contributed greatly to the progress of the Board during their 6-year terms. Dr. Jack Werner, Professor of Prosthodontics at the College of Physicians and Surgeons, School of Dentistry, San Francisco, and Dr. Gilbert P. Smith, Dean of the School of Dentistry, Columbia University, New York, were elected as new members of the Board.

The 1960 examination will be held at Georgetown University, School of Dentistry, Washington, D. C., July 25 through 30.

Information and applications for the 1961 examination may be secured from the Secretary, Dr. Charles H. Jamieson, 563 David Whitney Building, Detroit 26, Michigan.

THE AMERICAN BOARD OF PROSTHODONTICS

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Dr. Bertram H. Downs	629 N. Nevada Ave., Colorado Springs, Colo.
Dr. Alvin H. Grunewald	213 Washington St., Lake Bluff, Ill.
Dr. Jack Werner	College of Physicians and Surgeons, School of Dentistry, 344 Fourteenth St., San Francisco 3, Calif.
Dr. Gilbert P. Smith	430 W. 116th St., New York, N. Y.

DIPLOMATES 1960

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Arthur E. Aull, Jr.	7601 Seville Ave., Huntington Park
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Wilfred H. Terrell	595 E. Colorado Blvd., Pasadena
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John B. LaDue	25 E. Washington St., Chicago 2
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Robert B. Peters	730 N. Oak St., Hinsdale
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Carl T. Ostrem	704 Equitable Bldg., Des Moines
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Alfred W. Chandler	5209 Andover Rd., Chevy Chase 15
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F. Noel Smith	617 Medical Arts Bldg., Baltimore 1
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David J. Baraban	358 Commonwealth Ave., Boston 15
Frank A. Eich	1146 Beacon St., Brookline 46
Irving R. Hardy	Box 364, Middleboro
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Charles H. Jamieson	563 David Whitney Bldg., Detroit 26
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Richard H. Kingery	University of Michigan, School of Dentistry, Ann Arbor
P. C. Lowery	8545 Gratiot Ave., Detroit 13
Marion L. Mills	504 Security National Bank Bldg., Battle Creek
A. Alfred Nelson	245 W. Ten Mile Rd., Royal Oak
Chester K. Perry	16350 E. Warren Ave., Detroit 24
Albert J. Richards, Sr.	735-739 David Whitney Bldg., Detroit 26
Arthur Van Victor	25631 Gratiot Ave., Roseville
Minnesota	
Ralph H. Boos	808 Nicolett Ave., Minneapolis
Carlin K. Hayes	635 W. Third St., Hastings
Walter S. Warpeha	1312 Second St., N.E., Minneapolis 13
Missouri	
Emmett Beckley	1414 Professional Bldg., Kansas City 6
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Montana

Wallace W. Cloyd	114 N. Second St., Livingstone

Nebraska

Bert L. Cooper	1009 Sharp Bldg., Lincoln 8

Nevada

John E. Craddock	820 S. Seventh St., Las Vegas

New Jersey

L. Thomas Asche	37 James St., Newark 2
Martin J. Cain, Jr.	Hamilton Bldg., 43 W. Front St., Red Bank
James V. Giordano	425 Union Ave., Paterson 2
Charles M. Moore	205 Park St., Montclair
Leonard R. Moore	944 Stuyvesant Ave., Union

New York

I. Kenneth Adisman	100 Central Park, S., New York 19
Louis Blatterfein	1 Hanson Pl., Brooklyn 17
Sebastian A. Bruno	23-33 30th Ave., Astoria 2
Max P. Fishberg	Fajen Bldg., Main St., New City
Joel Friedman	499 Lincoln Pl., Brooklyn 38
Samuel Friedman	146 E. 49th St., New York 17
George W. Hindels	815 Fifth Ave., New York 21
William C. Hudson, Jr.	630 Fifth Ave., New York 20
Ira E. Klein	730 Fifth Ave., New York 19
Joseph S. Landa	136 E. 54th St., New York 22
Harold J. Levine	123 W. 57th St., New York 19
John J. Lucca	630 W. 168th St., New York 32
Richard C. Mast	123 E. 37th St., New York 16
Edward J. Mehringer	260 Smallwood Dr., Buffalo 26
Raymond J. Nagle	New York University School of Dentistry, 209 E. 23rd St., New York 10
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Max A. Pleasure	21-36 33rd Rd., Long Island City 6
Clyde H. Schuyler	400 Madison Ave., New York 17
Thomas E. J. Shanahan	861 Carroll St., Brooklyn 15
Sidney I. Silverman	80 Park Ave., New York 16
Gilbert P. Smith	430 W. 116th St., New York
Stanley G. Standard	225 W. 34th St., New York

North Carolina

Nathan R. Callaghan, Jr.	Veterans Administration Hospital, Fulton St. and Erwin Rd., Durham
Lucian G. Coble	330 Jefferson-Standard Bldg., Greensboro
David P. Dobson	University of North Carolina, School of Dentistry, Chapel Hill
Monte G. Miska	University of North Carolina, School of Dentistry, Chapel Hill

Ohio

Theodore A. Bodine	1207 Akron Savings & Loan Bldg., Akron 8
Carl O. Boucher	314 Beggs Bldg., 21 East State St., Columbus 15
James D. Chessrown	905 Mahoning Bank Bldg., Youngstown 3
Samuel S. Cohen	Park-Chester Medical Bldg., 10605 Chester Ave., Cleveland 6
Donald F. Cole	19840 Saranac Dr., Fairview Park 26
Walter J. Pryor	1026 Rose Bldg., Cleveland 15
John I. Sloan	1032 Rose Bldg., Cleveland 15

Oklahoma

Gustav A. Roelke	1112 Medical & Dental Arts Bldg., Tulsa 3

Oregon

Saul C. Robinson	401 Professional Bldg., 1033 S.W. Yamhill St., Portland 5
Merrill G. Swenson	611 S.W. Campus Dr., Portland

Pennsylvania

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Muller M. DeVan	Spruce Medical Bldg., 269 S. Nineteenth St., Philadelphia 3
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Edmund A. Travaglini	107 Rollins Rd., Carroll Park, Philadelphia 31
Russell W. Tench	4126 Wilshire Dr., York
Walter F. Wade	805 Myrtle St., Erie

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Elmer E. Francis	708 Hickman Bldg., Memphis 3
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Herman C. Levitch	University of Tennessee, College of Dentistry, 847 Monroe Ave., Memphis
W. D. Pearson	938 McCallie Ave., Chattanooga 3

Texas

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Emet P. Dickson	603 First National Bank Bldg., Paris
Frederick C. Elliott	The Texas Medical Center, 1133 M.D. Anderson Blvd., Houston 25
Edgar T. Gillean	1219 Medical Arts Bldg., Dallas 1
Thomas H. Kennedy	35 Highland Park Shopping Village, Dallas 5
Frederick R. Krug	2530 Savannah Ave., El Paso
John D. Larkin	791 Edgewater, New Braunfels
Lewis C. Turner	845-847 Milam Bldg., San Antonio 5

Virginia

Stuart J. Horner	1016 W. Franklin St., Richmond 20
Alexander L. Martone	1503 Colley Ave., Norfolk 7
Douglas C. Wendt	3108 Tenth Road, N. Arlington

Washington

Charles S. Ballard	1129 Medical-Dental Bldg., Seattle 1
Bernard Jankelson	652 Stimson Bldg., Seattle 1
Arne G. Lauritzen	1314 Lakeside Ave., S., Seattle 44

West Virginia

Edward J. deKoning	Professional Bldg., 1300 Market St., Wheeling
Jed C. Wilcoxen	708 Second St., St. Marys

Wisconsin

Ralph A. Behnke	5726 W. National Ave., West Allis 14
Lawrence W. Gabert	14235 W. Wisconsin Ave., Elmgrove
Daniel H. Gehl	324 E. Wisconsin Ave., Milwaukee 2
Joseph E. Hoffman	606 W. Wisconsin Ave., Milwaukee 3

Puerto Rico

Arthur H. Schmidt	School of Dentistry, University of Puerto Rico, San Juan 22

DIPLOMATES IN THE ARMED SERVICES 1960*

Leslie R. Allen, Lt. Col., USAF (DC)	19615 A-USAF (DC) USAF Hosp., Box 95, Tachikawa, APO 323, San Francisco, Calif.
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Perry W. Bascomb, Lt. Col., DC, USA	Dental Det. USA Garrison, Fort Riley, Kan.
Roy L. Bodine, Jr., Col., DC, USA	020484 Qtrs. 2, Ft. Kamehameha (Hawaii), APO 953, San Francisco, Calif.
John F. Bowman, Capt. (DC) USN	37 Narbrook Park, Narberth, Pa.
Allen A. Brewer, Lt. Col., USAF (DC)	Box 160 S.A.M., Randolph Field, Texas
Milton H. Brown, Capt. (DC) USN	Naval Dental School, National Naval Medical Center, Bethesda, Md.
Sebastian J. Campagna, Major, DC, USA	Dental Dept., US Military Academy, West Point, N. Y.
Judge C. Chapman, Capt. (DC) USN	Dental Clinic, US Naval Air Station, Pensacola, Fla.
John P. Christensen, Col., DC, USA	25 General Plaza, Fort Dix, N. J.
Henry A. Collett, Capt. (DC) USN	Dental Dept., Box 50, US Naval Air Station, Jacksonville 12, Fla.
Walter W. Dann, Capt. (DC) USN	US Naval Dental Clinic, Navy No. 128—F.P.O., San Francisco, Calif.
Walter J. Demer, Capt. (DC) USN	US Naval Dental Clinic, US Naval Gun Factory, Washington 25, D. C.
Louis Emory, Lt. Col., DC, USA	2nd Field Hospital, APO 407, New York, N. Y.
Pierre O. Evans, Col., DC, USA	Box 6306—Fitzsimmons Army Hospital, Denver 30, Colo.
James M. Fairchild, Lt. Col., DC, USA	US Army Dispensary, Room 2-D-201, The Pentagon, Washington 25, D. C.
George B. Foote, Col., DC, USA	Baylor University, College of Dentistry, 800 Hall, Dallas 10, Texas
William MacD. Fowler, Capt. (DC) USN	Dental Detachment, Marine Corps Recruit Depot, Parris Island, S. C.
Arthur R. Frechette, Capt. (DC) USN	Bureau of Medicine and Surgery, Dental Department, Washington 25, D. C.
John R. Frost, Lt. Col., DC, USA	538 Wheaton Rd., Fort Sam Houston, Texas
Oren H. Gaver, Comdr. (DC) USN	Camp Dental Department, Marine Corps Base, Camp Lejeune, N. C.
W. Irwin Gullett, Capt. (DC) USN	250 Tamarack Ave., Carlsbad, Calif.
Charles M. Heartwell, Capt. (DC) USN	5440 Argall Crescent, Norfolk, Va.
Charles D. Hemphill, Capt. (DC) USN	1467 Jefferson St., San Francisco 23, Calif.
David Henderson, Capt. (DC) USN	US Naval Dental Clinic, Navy No. 115 F.P.O., New York, N. Y.
Frank E. Jeffreys, Capt. (DC) USN	Dental Department, Naval Station, Long Beach, Calif.
Frank C. Jerbi, Lt. Col., DC, USA	307 Austin Loop, Fort Benning, Ga.
Stephen T. Kasper, Capt. (DC) USN	Dental Department, U.S. Naval Station, Treasure Island, San Francisco 30, Calif.
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Frank J. Kratochvil, Jr., Comdr. (DC) USN	4023 Wexford Dr., Kensington, Md.
Frank M. Kyes, Capt. (DC) USN	Dent. Dept., Ad. Com., USN TC, Great Lakes, Ill.
James B. Lepley, Capt. (DC) USN	US Naval Hospital Dent. Service, San Diego 34, Calif.
Donald O. Lundquist, Capt. (DC) USN	Madigan Army Hospital, Tacoma 99, Wash.
Robert B. Lytle, Capt. (DC) USN	US Naval Dental School, National Naval Medical Center, Bethesda 14, Md.
William M. Marking, Capt. (DC) USN	4995 Cuba Millington Rd., Millington, Tenn.
Allen L. McInturff, Capt. (DC) USN	MOQ—2216 USMC, Camp Lejeune, N. C.
Charles W. Miller, Capt. (DC) USN	Apt. 3A—88-35 162nd Street, Jamaica 32, N. Y.

*All of these addresses are subject to change.

Gordon L. Miller, Capt. (DC) USN	262 Sereno Dr., Vallejo, Calif.
Paul A. Miller, Lt. Col., DC, USA	196th Station Hospital, A.P.O. 163, New York, N. Y.
James B. Neil, Col., DC, USA	Box 195, Letterman Army Hospital, Presidio of San Francisco, San Francisco, Calif.
John V. Niiranen, Capt. (DC) USN	Force Dental Officer, Headquarters, F.M.F. Pacific, c/o Fleet Post Office, San Francisco, Calif.
Benjamin W. Oesterling, Capt. (DC) USN	4531 Cover St., Riverside, Calif.
Edmund S. Olsen, Jr., Lt. Col., DC, USA	Central Dental Laboratory, Reed Army Medical Center, Washington 12, D. C.
Raymond H. Osterholtz, Major, DC, USA	1123 Duane Ave., Rolla, Mo.
Mack L. Parker, Capt. (DC) USN	Bureau of Medicine & Surgery, Navy Department, Washington 25, D. C.
Kenneth D. Rudd, Lt. Col., USAF (DC)	Box 1559, Lackland A.F.B., San Antonio, Texas
Jack H. Sault, Capt. (DC) USN	511 Byron St., Palo Alto, Calif.
Clare W. Sauser, Lt. Col., DC, USA	180 N. Ridge St., Southern Pines, N. C.
Julius C. Sexson, Col., DC, USA	024630, Dental Det., Fort Ord, Calif.
Edwin H. Smith, Jr., Lt. Col., DC, USA	5306 Baltimore Ave., Chevy Chase 15, Md.
John B. Stoll, Capt. (DC) USN	N.A.A.S., Dental Dept., Kingsville, Texas
Harold R. Superko, Capt. (DC) USN	U. S. Naval Hospital, Oakland, Calif.
Christopher E. Thomlinson, Capt. (DC) USN	11th Force Dental Company (Aviation) Marine Wing Headquarters Group—1st Marine Aircraft Wing, Aircraft, F.M.F. Pacific, c/o Fleet P. O., San Francisco, Calif.
Herbert J. Towle, Jr., Capt. (DC) USN	7917 Sleaford Pl., Bethesda 14, Md.
Myron G. Turner, Capt. (DC) USN	Dental Dept., U. S. Naval Air Station, North Island, San Diego 35, Calif.
Robert L. Walsh, Col., DC, USA	Sixth U. S. Army Central Dental Lab., 2155 Webster St., Alameda, Calif.
Robert H. White, Lt. Col., DC., USA	L/C—O—1702671—665 Med. Det., APO 301, San Francisco, Calif.

READERS' ROUND TABLE

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

When I read the article of Lindell L. Leathers in the January-February JOURNAL, [J. PROS. DEN. 10:5-13, 1960] I noted on page 10 a suggested formula for a powder consisting of penicillin and sulfanilamide mixed with denture adhesive powder, to be placed inside an immediate denture.

Upon reading this, I recalled reading in other literature that small amounts of penicillin were more likely to result in sensitivity, and also, I recalled references to the undesirability of topical application of the product.

I wrote Eli Lilly & Company and gave them reference to the article mentioned above and stated my belief as mentioned above.

I enclose their answer for your consideration. For one of my limited knowledge, to question Doctor Leathers' advice may border upon impertinence, but I do so with firm belief that my position is correct, as based upon published literature on the various aspects of penicillin.

Sincerely,

CHARLES L. NELSON, D.D.S.

Encl.

(The answer of Eli Lilly & Company follows.)

INDIANAPOLIS, IND.

MEDICAL DIVISION
ELI LILLY & COMPANY

GENTLEMEN:

Re: Inquiry of Dr. Charles L. Nelson concerning the use of powdered penicillin with powdered sulfanilamide in dentures.

I think Dr. Nelson is justified to question the use of powdered penicillin in conjunction with powdered sulfanilamide in a paste form as applied to the inside of the denture over an area of recent extraction and that his reasoning based upon the literature is sound. I personally do not recommend using powdered penicillin with sulfanilamides applied in combination in dentures wherein the drugs are loosely applied to the mucous membrane.

If the drugs are to be applied to extraction sites in immediate dentures, they should be placed directly in the socket. Thus, the drugs are placed in close contact with the blood, and as such, I doubt if the allergic tendency is likely to develop. I do think drugs with the lowest incidence of creating allergic manifestations when used in this manner should be used and this is the reason why erythromycin is the better agent to use.

Very truly yours,

RONALD S. PING, D.D.S.

NEW YORK, N. Y.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

In your comment on my article which appeared in the March-April issue of the JOURNAL OF PROSTHETIC DENTISTRY, "The Hinge Axis and Its Practical Application in the Determination of Centric Relation" [J. PROS. DEN. 10:248-257, 1960], you mention: "There may be some question about the desirability of using external force on the mandible *at the time* the registration is made." Possibly I was not clear in my description of the method I use to register centric [relation], but from your statement it appears to me that you assume that I have the patient wear the "trainer" during the registration. I specifically mention in the article that the "trainer" is removed prior to the registration.

If you refer to the pressure on the chin (downward and backward), this procedure is followed in order to (1) guide the patient to close in the terminal hinge position and (2) cause the patient's muscles of mastication (except the external pterygoids) to carry the condyles into the glenoid fossae as far as they can go without external force. It is not the dentist who carries the condyles into the fossae, but rather the dentist helps guide the patient so that his (the patient's) own muscles will carry the condyles to the physiologically correct relationship.

I hope this will clear up any misunderstanding that may be construed from the article.

Sincerely,

RAYMOND COHEN, D.D.S.

BROOKINGS, S. D.

ST. PETERSBURG, FLA.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

Being very much interested in the research articles published in the JOURNAL OF PROSTHETIC DENTISTRY, I studied the article "Registration of the Condyle Path Inclination: Variations Using the Gysi Technique," written by Doctors Posselt and Skytting, in the March-April issue [J. PROS. DEN. 10:243-247, 1960].

After reading the first sentence of the article, I turned to reference 1 and found that the article concerned in the reference has yet "to be published." True that Table I states the findings of the reference article; however, one does not have the opportunity to learn *how* the authors arrived at their results so that the reader may evaluate the validity of their findings. Reference 10 also states that the article concerned is "in press." Again, the opportunity for evaluation by the reader is missing. It would seem that the present article should not have been submitted or should have been withheld from publication until complete references became available to the reader.

Continuing further, Doctors Posselt and Skytting state that the first aim of their investigation was "(1) to assess any variations of *sagittal** condyle path inclination as obtained by graphic recording. . . ." This was to be accomplished as stated by the authors in the second paragraph: "In the Gysi technique, the condylar rods of the face-bow make tracings on cards held on the balancing sides during alternate *lateral** movements." Two discrepancies become immediately manifested: (1) Obviously, a *sagittal* condyle path inclination is not registered by having the patient make alternate *lateral* movements. (2) By having the patients make alternate lateral movements to make the registrations, Doctors Posselt and Skytting did not follow the Gysi technique as suggested by their own reference 4: "The Gysi Face-Bow (Directions for

*The italics are Dr. Trapozzano's.

Use), New York, 1935, The Dentists' Supply Company of New York." In this reference, the section germane to the subject is headed "Sagittal Condyle Registration." Under the heading on pages 16, 17, 18 is stated the following:

"After locking the tracing point of the incisor path marker out of contact with the Gothic arch registering table, hold a card which has been blackened with a lamp-black pencil between the face-bow tracing point and the tissues of the face on one side in such a way that the lower border of the card, which should be straight, is parallel to the mirror-plate of the face-bow. Be sure that the card is parallel to the face-bow before movements of the mandible are made. This is easily checked by seeing that the reflected border of the card on the mirror-plate of the face-bow is parallel to the real border of the card. Release the point of the side to be registered. Have the patient move the mandible *forward and backward,** thereby registering the condyle path on the card. These mirror-plates are adjusted to the various widths of heads by simply moving in or out."

Note that the reference specifically states, "Have the patient move the mandible *forward and backward,** thereby registering the condyle path on the card." No mention is made of "alternate lateral movements."

I trust these comments will be accepted in the impersonal spirit in which they are offered.

Sincerely,

VINCENT R. TRAPOZZANO, D.D.S.

MALMÖ, SWEDEN

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

Dr. Trapozzano regrets that he has been unable to read the articles referred to as references 1 and 10. Although reference to articles accepted for publication is an accepted practice, I do agree that it would have been better if the articles referred to as 1 and 10 had been available. In fact, the article dealing with registration of the condyle path by intraoral wax records (reference 1) was submitted for publication 1½ months before the present article. However, due to technical difficulties with one of the figures, the article on the wax records was delayed, and the article "Registration of the Condyle Path Inclination: Variations Using the Gysi Technique" [J. PROS. DEN. 10:243-247, 1960], therefore, was published first. It was my understanding that the other article would appear first and that the date of publication would be noted in the reference listing.

I expect, however, that the article on the wax records will appear in the next issue of the JOURNAL OF PROSTHETIC DENTISTRY [see J. PROS. DEN. 10:441-454, May-June, 1960]. The article referred to as reference 10 has been published in the meantime. As Dr. Trapozzano realizes, very often more than a year may elapse between the submission of a manuscript and its eventual publication.

As regards the next point made by Dr. Trapozzano, it is true that in the instructions of the Dentists' Supply Company forward and backward movements are suggested. It is a well-known fact that the projection of the path of the balancing condyle on the sagittal plane will differ slightly depending on whether the mandible is moved forward and backward or forward and slightly medially. However, these differences are hardly perceptible in the beginning of the path, which is the section used for making tangential lines for measuring the inclination of the condyle path.

It was necessary for the writers to adapt the recording method, which was originally designed for edentulous patients, to dentulous patients. Accordingly, the lateral movements were substituted for forward and backward movements because the patients' incisors "tripped" over the split of the two-piece lower clutch. This was avoided in lateral movement.

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*The italics are Dr. Trapozzano's.

As mentioned in the article, a wax-glass plate was substituted for the cardboard in order to obtain a more permanent record etched on the glass.

I hope that these observations will help to answer Dr. Trapozzano's comments.

Sincerely,

ULF POSSELT, D.D.S., ODONT. DR.

VENTURA, CALIF.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

I have heard of upside-down understanding, but I never saw it so well exemplified as in your discussion [J. PROS. DEN. 10:403, 1960] of my article, "Why Dental Restorations Should Have Cusps" [J. PROS. DEN. 10:553-555, 1960].

On page 555, I make it very clear and explicit that the cusps of the molars and bicuspids are all fully formed in wax *before* the cuspids are waxed and that the cuspids are restored only after shapes have been given to the molars and bicuspids.

I do not subscribe in any way to the belief that the buccal inclinations of the lower buccal cusps and the lingual inclinations of the upper buccal cusps are in any way related to the cuspid slopes.

I think you have concluded that I have the same idea of cusp antagonisms as has been promoted by some East Coast dentists, which is not the case.

Very truly,

CHARLES E. STUART, D.D.S.

Editor's note.—The editor has demonstrated his right to be wrong. The sentence on page 403 in the "Through the Eyes of the Editor" section should have read: "He develops the occlusal forms of the posterior teeth in wax before he shapes the lingual surfaces of the patterns for the cuspid restorations." I apologize for the before-after transposition.

Carl O. Boucher, Editor

NEWS AND NOTES

MEETINGS

Pacific Coast Society of Prosthodontists, Miramar Hotel, Santa Monica, Calif., Aug. 4 to 6, 1960.

Swedish Dental Society, Centennial Meeting, Stockholm's Concert Hall and Apollonia, Stockholm, Sweden, Aug. 17 to 20, 1960. For further information write to Torsten Telander, Secretary, Swedish Dental Society, Nybrogatan 53, Stockholm Ö, Sweden.

Fourth National Cancer Conference sponsored by the American Cancer Society, National Cancer Institute, Minneapolis, Minn., Sept. 13 to 15, 1960. The theme of the Conference is "Changing Concepts Concerning Cancer." For further information write to the American Cancer Society, Inc., Medical Affairs Dept., 521 West 57th St., New York 19, N. Y.

Canadian Dental Association, Ottawa, Canada, Sept. 25 to 28, 1960.

American Society of Oral Surgeons, Westward Ho Hotel, Phoenix, Ariz., Oct. 12 to 15, 1960. For further information write to Mr. D. C. Trexler, Executive Secretary, 840 North Lake Shore Dr., Chicago 11, Ill.

American Academy of Periodontology, Miramar Hotel, Santa Monica, Calif., Oct. 13 to 15, 1960. The theme of the scientific program is "The Role of the Tooth in Periodontal Health and Disease."

American Denture Society, Beverly Hilton Hotel, Los Angeles, Calif., Oct. 14 and 15, 1960.

Mid-Continent Dental Congress, Chase Hotel, St. Louis, Mo., Nov. 27 to 30, 1960. For further information write to the St. Louis Dental Society, 8013 Maryland Ave., St. Louis 5, Mo.

Greater New York Dental Meeting, Statler Hilton Hotel, New York, N. Y., Dec. 5 to 9, 1960. For further information write to Mrs. Mabel Purdy, Executive Secretary of the Meeting, Room 106A, Statler Hilton Hotel, New York 1, N. Y.

American Equilibration Society, Sheraton-Blackstone Hotel, Chicago, Ill., Feb. 2, 1961. For further information write to Dr. R. C. Van Dam, Secretary, 11431 S. Halsted St., Chicago, Ill.

American Association of Endodontists, Conrad Hilton Hotel, Chicago, Ill., Feb. 2, 1961. For further information write to Dr. Edwin C. Van Valey, Secretary, 9 Rockefeller Plaza, New York 20, N. Y.

American Academy of Restorative Dentistry, Conrad Hilton Hotel, Chicago, Ill., Feb. 4 and 5, 1961.

American Academy of Crown and Bridge Prosthodontics, Conrad Hilton Hotel, Chicago, Ill., Feb. 4 and 5, 1961.

ANNOUNCEMENTS

The supply of copies of the first edition of the *Glossary of Prosthodontic Terms* has been exhausted. Copies of the second edition will be available by Sept. 1, 1960. Glossaries will be supplied to those whose orders have been received as soon as they are available.

Reprints of "Principles, Concepts, and Practices in Prosthodontics" may be obtained by writing Dr. W. Les Warburton, Secretary-Treasurer, Academy of Denture Prosthetics, 807 Medical Arts Bldg., Salt Lake City 11, Utah. The price is 25 cents per copy, with a 20 per cent discount allowed on purchases of 20 or more copies. Cash, check, or purchase order *must* accompany the order.

Reprints of the article, "The Microbiology of Plastic Dentures," by William W. Leathen, Norma A. Kinsel, Craig C. Brown, and William F. Swanson (J.A.D.A. 60:164-170, 1960) may be obtained without cost by writing to Mellon Institute, 4400 Fifth Ave., Pittsburgh 13, Pa.

POSTGRADUATE COURSES

Boston University, School of Medicine, Division of Graduate Studies, Department of Stomatology, announces the following postgraduate courses:

Occlusal Adjustment, Dr. Bernard S. Chaikin, Dr. Henry M. Goldman, Dr. Gerald M. Kramer, Dr. William Pendergast, Dr. Jack Bloom, and associates, Sept. 12 to 16, 1960.

Endodontics, Dr. Herbert Schilder, Sept. 12 to 16, 1960.

Periodontal Therapy, Dr. Henry M. Goldman, Dr. Bernard S. Chaikin, Dr. Gerald M. Kramer, Dr. William Pendergast, Dr. Jack Bloom, and associates, Nov. 7 to 11, 1960.

Fixed Bridge Prosthesis, Dr. Leo Talkov, Dr. David J. Baraban, and Dr. Lloyd Warshauer, Nov. 14 to 18, 1960.

Full Denture Prosthesis, Dr. Chester Landy, Dec. 12 to 16, 1960.

For further information write to Director of Postgraduate Studies, Department of Stomatology, Massachusetts Memorial Hospitals, 750 Harrison Ave., Boston 18, Mass.

Boston University, School of Medicine, offers 1-year courses in Oral Surgery and Endodontics and courses of 2 academic years in Orthodontics and Prosthodontics.

For further information concerning these courses write to Department of Stomatology, Boston University, School of Medicine, 80 East Concord St., Boston 18, Mass.

Indiana University, School of Dentistry, announces the following postgraduate course:

Course for Laboratory Technicians on Partial Denture Design and Construction, July 25 to 28, 1960.

For further information and application write to Indiana University, School of Dentistry, 1121 West Michigan St., Indianapolis 2, Ind.

The University of North Carolina, School of Dentistry, announces the following postgraduate courses:

Dentistry For Children II, July 18 to 22, 1960.

Dentistry For Children III, July 25 to 29, 1960.

For further information and application write to Office of Postgraduate Dental Instruction, School of Dentistry, P. O. Box 750, Chapel Hill, N. C.

Temple University School of Dentistry announces the following postgraduate course:

Graduate Orthodontics, Sept. 12, 1960, a 2-year course.

For further information and application write to Dr. Louis Herman, Director of Postgraduate Studies, Temple University School of Dentistry, 3223 North Broad St., Philadelphia 40, Pa.

Tufts University School of Dental Medicine announces the following postgraduate course:

A Special Participation Course in Periodontology, Oct. 31 to Nov. 4, 1960.

Applications are now being accepted for two Research Fellowships in Oral Pathology and Periodontology for the school year beginning September, 1960.

For further information and application write to Director of Graduate and Postgraduate Studies, Tufts University School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

LABORATORY TECHNOLOGY ANNOUNCEMENTS

AMERICAN DENTAL ASSOCIATION PROGRAM FOR DENTAL LABORATORY TECHNICIANS

A special program for dental laboratory technicians will be presented at 9:00 A.M., Thursday, Oct. 20, 1960, as part of the essay program at the American Dental Association's 1960 meeting in Los Angeles, Calif. The participants in the October 20 program and their subjects are as follows:

Moderator: J. Eugene Ziegler, Los Angeles, Chairman of the American Dental Association Council on Dental Trade and Laboratory Relations.

Occlusion in Complete Dentures: Clyde H. Schuyler, New York, Chairman, Committee on the Education and Certification of Dental Laboratory Technicians, American Dental Association Council on Dental Education.

Analysis of Newer Dental Materials and Techniques of Interest to the Dental Technician: Ralph Phillips, Indianapolis, Chairman and Professor, Department of Dental Materials, Indiana University, School of Dentistry.

Waxing of Full Reconstruction Cases: Charles E. Stuart, Ventura, Calif.

Panel Discussion.

Association President Paul H. Jeserich and NADL President Ugo S. Garganese will also participate in the special program.

Dental laboratory personnel who meet one of the following criteria and are registered at the 1960 meeting will be admitted to the October 20 program:

1. All certified dental laboratory technicians.
2. All dental laboratory technicians employed by licensed dentists.
3. Dental laboratory owners who are members of the National Association of Dental Laboratories.
4. Employees of NADL member laboratories.

DENTAL LABORATORY TECHNOLOGY COURSE

The Ohio State University, College of Dentistry announces that it is receiving applications of students for the Curriculum of Dental Laboratory Technology. This course of study of the laboratory phases of prosthodontics extends over 2 academic years and leads to a Certificate of Graduate Dental Laboratory Technologist.

Application forms may be obtained by writing to the Entrance Board, Ohio State University, Administration Bldg., 190 North Oval Dr., Columbus 10, Ohio. Applications should be received by the Entrance Board by Aug. 1, 1960, for admission to the class starting Sept. 26, 1960.

For further information write to the Chairman of Dental Laboratory Technology, Ohio State University, College of Dentistry, 305 West Twelfth Ave., Columbus 10, Ohio.

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Next Meeting: Miramar Hotel, Santa Monica, Calif., Aug. 4 to 6, 1960.

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Next Meeting: Americana Hotel, Miami Beach, Fla., May 18 to 21, 1961.